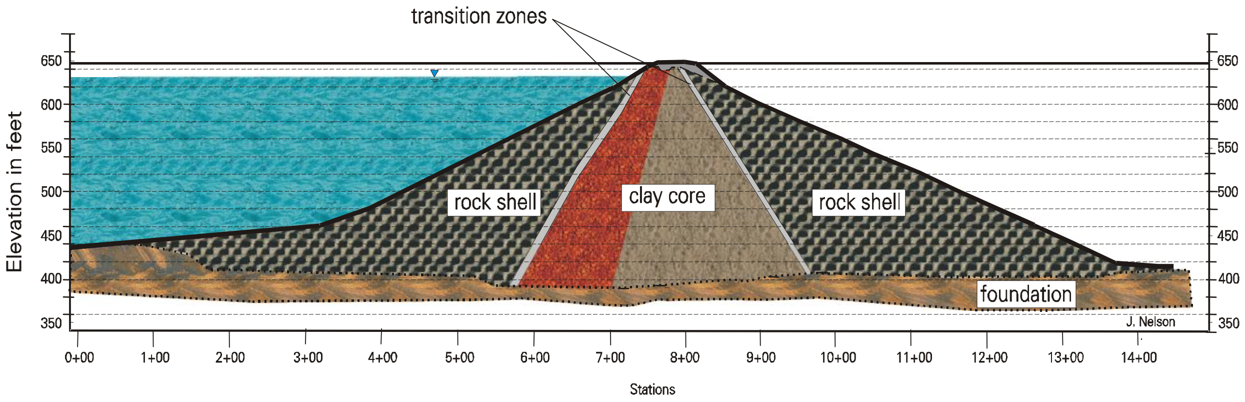
January 2009

THIRD INTERIM
SURVEILLANCE REPORT
December 2006 through December 2008
LEROY ANDERSON DAM NO. 72-9,
Santa Clara County



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TELEPHONE (408) 265-2600
FACSIMILE (408) 266-0271
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January 22, 2009

Mr. David A Gutierrez, Chief
Division of Safety of Dams
Department of Water Resources
1416 Ninth Street
P.O. Box 942836
Sacramento, CA 94236-0001

Subject: Leroy Anderson Dam, No. 72-9
Third Interim Surveillance Report, Dec 2006 – Dec 2008

Dear Mr. Gutierrez:

Enclosed with this letter are two copies of our third interim surveillance report for Leroy Anderson Dam covering the period from December 2006 to December 2008. There were no major incidents or changes at the dam during this period.. The report includes analysis of data from the existing pneumatic piezometers, crest monuments, seepage weirs, visual reconnaissance and analysis of new DIP piezometer data. There were no major incidents or changes at the dam during 2008. In general, there are no substantive changes in dam or reservoir response compared to previous years.

On August 31, 2006, District staff (S. Wallis, M. Mooers, and J. Nelson) and DSOD field engineer Aspet Ordoubigian performed an annual DSOD site inspection of Anderson Dam and appurtenant facilities. On November 14, 2007, DSOD field engineer Aspet Ordoubigian, with several District employees (D. Hook, J. Aguilera, J. Bozzo, M. Mooers, and S. Wallis) performed a fall inspection. No conditions were noted that would affect the continued safe performance of the dam.

If you have any questions or comments regarding this report, please contact Mr. James L. Nelson, Senior Engineering Geologist, at 408-265-2607, extension 2667.

Sincerely,

David E Hook

David E. Hook, P.E.
Engineering Unit Manager
Dam Safety Program Unit

Enclosures

cc: w/encl. D. Hook, D. Gilleland, M. Mooers, J. Nelson, B. Baker, library (4)
cc: w/o encl. J. Fiedler, C. Elias, R. Jacobs

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THIRD INTERIM
SURVEILLANCE REPORT
December 2006 through December 2008
LEROY ANDERSON DAM NO. 72-9,
Santa Clara County

Date of photo 10/10/06

Prepared for:

State of California
Department of Water Resources
Division of Safety of Dams
P.O. Box 942836
Sacramento, CA 95236

Prepared by:
Santa Clara Valley Water District
5750 Almaden Expressway
San Jose, CA 95118

January 2009

THIRD INTERIM
SURVEILLANCE REPORT
December 2006 through December 2008
LEROY ANDERSON DAM NO. 72-9,
Santa Clara County

Surveillance Reporting Period:

Pneumatic Piezometer and Rainfall Data from January 1994 through November 2008
New Vibrating Wire Piezometer Data from late 2006 through December 2008
New Spillway Weirs #1 and #2 from April 2000 through November 2008
Crest and Spillway Monument Data from June 1988 through October 2008

The analysis and interpretation of the instrumentation and other relevant data presented in this report has involved the application of certain graphical and statistical interpretive techniques common to the geosciences and earth dam engineering professions. The conclusions presented in this report were developed upon evaluating the performance of all instruments and other pertinent data during the specified period, and represent the professional judgment of its authors. This report was submitted on January 22, 2009.

JAMES LEWIS NELSON
No. 1463
CERTIFIED ENGINEERING GEOLOGIST

Report prepared by:

James L. Nelson, C.E.G.
Senior Engineering Geologist
Dam Safety Program Unit
Water Utilities Enterprise
Technical Support

Quality Control/Quality Assurance

This report has been reviewed and approved for publication by the undersigned professional engineer. We attest and confirm that the report was prepared by the individual who signed the report under our immediate direction and supervision and that the conclusions and recommendations presented herein are reasonable and supported by District management.

Reviewed and approved by:

David E. Hook, P.E.
Engineering Unit Manager
Dam Safety Program Unit

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J. Nelson Memorandum to Y. Arroyo dated November 4, 2008: *Observations of Additional Landslides During Repair of the Boat Ramp Landslide, Anderson Dam & Reservoir*, 7 pages

1.0 INTRODUCTION

1.1 Scope and Purpose

This Third Interim Report contains surveillance data collected from Anderson Dam, No. 72-9, from December 2006 through December 2008. The focus of this Interim Report is to review the data for overall accuracy and to make assessments of general data trends. If any significant geotechnical or operational events have occurred (i.e., earthquakes, sustained elevated reservoir levels, significant operational or maintenance changes, or dam instrumentation/monitoring changes), these are addressed to the appropriate level in this report.

Starting with this report we are only providing historic data plots covering the last 10 years (since ~ 1998). The reader is referred to previous reports for earlier data plots.

1.2 New Instrumentation and Current Studies

Currently, the District has retained AMEC Geomatrix Consultants to complete a preliminary conservative analysis of the seismic stability evaluation (SSE) of Anderson Dam, which was completed by December 24, 2008 (AMEC, 2008). The SSE work also includes a detailed seismotectonic study by William Lettis Associates for all District Dams. A second phase of work is scheduled for the SSE that will include additional field and laboratory investigations estimated to be performed in 2009 and analysis and report by late 2010. The District will continue to keep DSOD informed and involved regarding the SSE study results for Anderson Dam.

Additional work is also being completed for the District by GEI Consultants in association with the last 5-yr FERC Part 12 safety inspection and review (GEI, 2007). This work has to do with confirmation of the existence of both upstream and downstream transition zones separating the impervious core from the upstream and downstream rockfill zone. GEI is also developing alert levels for all geotechnical instrumentation recently installed in the dam. Both elements of work are scheduled to be finished in early 2009. The District will forward these reports to DSOD when completed.

2.0 BACKGROUND INFORMATION AND METHODOLOGY

During the time period covered by this report, the District monitored 2 pneumatic piezometers in the dam, 2 spillway underdrain seepage weirs, 15 dam crest survey monuments, and 3 spillway training wall survey monuments. For the first time, we present data plots from late December 2006 to the present for 31 vibrating wire piezometers, installed during the 2006/2007 Dam Instrumentation Project (DIP). The locations of crest monuments, spillway training wall monuments, original and new piezometers, accelerometers, and the spillway underdrain weirs at Anderson Dam are shown in plan in Figure 1, and in section in Figures 2 through 4. Specifically, Figure 2 presents a transverse cross section A-A’ through a minor section of the left abutment of the dam. Figure 3 presents cross section B-B’ near the maximum section of the dam. Figure 4 presents a transverse section C-C’ along the crest. The sections show new vibrating wire piezometers, original pneumatic piezometers, and open well piezometer OW-1.

All new data covered in this report is presented in tabular form, and plotted to facilitate review. Table 1 summarizes pertinent information regarding the vibrating wire piezometers including tip location in the respective section of dam, tip elevation, surface elevation, and construction method used (“grout-in” versus “sand-pack”) during installation. Table 2 and a corresponding plot of the data in Figure 7 provides a convenient way to look at statistical multi-year reservoir trends as described in more detail in section *3.2 10-year Reservoir Fluctuation*.

Tables 3 through 5 summarize recent piezometer, weir, and surface monument survey data, respectively. All surveillance data are also shown graphically in Figures 8 through 13, and discussed later in the report. For the period of this report, data were collected annually for survey monument and monthly for original pneumatic piezometers and underdrain weirs. Data were collected from the new vibrating wire piezometer at various intervals as summarized in section *2.1 General Surveillance*. Crest monuments were surveyed at the times indicated (typically near the end of every year).

All elevation data presented in this report have been adjusted for the current datum used by the District which is the North American Vertical Datum (NAVD) 1988, which is 2.80 feet higher than the old datum National Geodetic Vertical Datum (NGVD) at this location.

2.1 General Surveillance

General surveillance tabular data are summarized on Tables 3 through Table 5. This report includes approximately 2 years of complete data from the new 31 DIP phase 1 vibrating wire piezometers, shown in Figure 1 in plan view and in Figures 2 through 4 in longitudinal and transverse section views.

Prior to installation of a new Automated Data Acquisition System (ADAS), data from new vibrating wire piezometers were manually collected 1 to 4 times a month. The ADAS that automatically collects piezometer data at frequent intervals (4 times a day) is currently (December 2008) operational. Prior to the operation of ADAS, data collection was generally tied to the rate of changes in reservoir elevation. Relatively rapid changes in reservoir resulted in more frequent reading and conversely, less rapid changes resulted in less frequent readings.

As mentioned above, data from the newly installed 31 vibrating wire piezometers has been collected for almost 2 years starting with their installation in late-December 2006 and continuing to early December 2008. During this period there have been minimal changes in reservoir elevations (total excursion of ~16 feet) and relatively low reservoir elevations (between 14 and 32 feet below spillway lip). The maximum reservoir elevation achieved in 2008 of el. 613.4 ft was slightly higher than the maximum reservoir elevation of 612 ft in 2007. In this report, for each new vibrating wire piezometer we present standard piezometer and reservoir plots versus time in Appendix A and cross plots showing piezometric data versus reservoir elevation in Appendix B.

The cross plots (Appendix B) are more likely to show subtle piezometric responses relative to minor changes in reservoir elevations (if applicable) because there is a more direct correlation between piezometric response and reservoir fluctuations than plots showing piezometric data versus time. Figures B-1 through B-31 includes individual cross plots for the 31 vibrating wire piezometers. In addition to showing possible trends and responses, these plots graphically show piezometer tip elevation, ground surface elevation above the piezometer tip, and spillway lip elevations.

Reported rainfall is measured at District Rain Gauge No. 41-2073, which is located a few hundred feet southeast of the left abutment of Leroy Anderson Dam.

2.2 Piezometers

2.2.1 Older Piezometers

Both pneumatic piezometers (PPA-1 and PPA-2), originally installed in 1975, show slight fluctuations and response to changes in reservoir levels but are still operational after 33 years of service. A gap in the data occurs from December 2001 through March 2002 due to problems with the pneumatic data collection instrument. The District began collecting water level data from open well piezometer OW-1 in September 2003 after the well was installed in August 2003.

2.2.2 New Vibrating Wire Piezometers

Table 1 summarizes the pertinent data of the new vibrating wire piezometers including location in the dam, tip elevation and surface elevation. The District has been manually collecting data from 31 vibrating wire (VW) piezometers since their installation in late December 2006, with ADAS beginning in December 2008. The locations of the VW piezometers are shown in plan view in Figure 1 and in section views in Figures 2, 3, and 4.

The new piezometers were installed at various locations of Anderson Dam as summarized in Table 1, including 16 VW piezometers in the downstream core (Zone 3) of the embankment, 1 VW piezometer in the upstream core (Zone 2) (with core piezometers shown as red symbols in Figures 2, 3, and 4), 3 VW piezometers in the downstream transition zone (yellow symbols), 2 VW piezometers in the upstream transition zone, 2 VW piezometers in alluvium/colluvium (green symbols), and 7 VW piezometers are in foundation Franciscan Complex bedrock (blue symbols).

2.3 Inclinometer

During drilling for the DIP from October 19, 2006 through October 27, 2006, the District’s contractor installed one in-place inclinometer casing at the crest through the maximum section of Anderson Dam into bedrock. The inclinometer casing is about 240 feet deep and penetrates about 15 feet into the underlying Franciscan Complex sandstone. The District has installed a series of electronic tiltmeter “Little Dipper” in-place inclinometers in the casing to monitor potential deformation of the dam. In addition, shortly after installation, the District collected manual inclinometer readings of the casing orientation. The ADAS system is currently collecting automated in-place inclinometer data at the same daily interval as the vibrating wire piezometer data. The continuous inclinometer data will be presented in next year’s annual surveillance report.

2.4 Spillway Underdrain System

The current spillway underdrain seepage monitoring program for Anderson Dam Spillway began in May 1993. At that time, the District only measured the "center" drainage system which collects seepage in the central portion of the spillway. The "left" drainage system discharged through boulders that were providing slope protection D/S of the spillway bucket and could not be measured.

The seepage system was modified with the construction of the two "V" notch seepage weirs in 1999 (with readings beginning April 2000) to allow for independent and unrestricted measurement of flows. Weir #1 continues to measure the seepage from the "center" drainage system but is not affected by the restriction and backpressure created by the use of a meter as was the old system that it replaced. Weir #2 measures the seepage collected along the left (southern) side of the spillway.

2.5 Surface Monuments

Modifications to Anderson Dam in 1986-87 included raising the dam crest 4 to 7 feet and widening of the spillway to accommodate new PMF discharge requirements. Consequently, new monuments were installed in 1988 along the crest and at the right and left abutments. Prior to the 1986-87 raise, crest monuments ran along a straight line alone the crest of the dam similar to over District dams. However, the locations of survey monuments installed in 1988 at Anderson Dam alternate from the upstream to downstream side of the crest.

Before 1988, and the introduction of GPS surveys with the resulting data provided in the form of coordinates (Northings and Eastings), previous transverse data consisted of offset displacements either upstream or downstream relative to the monument line established soon after the dam was constructed.

As discussed below in more detail, to further simplify our annual interim surveillance reports, we have made a significant change in the way that yearly survey data are presented in both tables and data plots.

Survey of monuments at Anderson Dam consists of using GPS techniques with data format in X-Y coordinates (eastings and northings, respectively). Previous survey techniques of the original crest monuments consisted of offset (transverse) displacements either upstream or downstream relative to the monument line established soon after the dam was constructed. These data are calculated from the coordinate data using trigonometric relationships assuming stable reference points away from the dam and located in the right and left abutments. The reference baseline for the transverse displacement calculation uses the coordinates of the end points, assumed to be relatively stable monuments in bedrock immediately right and left of the dam, at the time the survey was first established. It should be noted that the GPS survey (northing, easting, and vector displacements) do not utilize local stable endpoints, but a regional GPS station, and thus produce somewhat different results with respect to points of reference.

As discussed below in more detail, to further simplify our surveillance reports, we have made a significant change to the way survey data are presented in tables and data plots. We use a new method of determining lateral displacements know as the Resultant Double Difference (RDD) method.

2.5.1 Lateral Displacement using Resultant Double Differences (RDD)

Since the 2006 surveillance report (Nelson and Volpe, 2007) we analyzed survey data using a new methodology referred to as the Resultant Double Differences (RDD) to monitor lateral displacements. This method involves calculating the cumulative change in distance in the X (eastings) and Y (northings) directions between a reference monument on a particular structure and each successive monument in-line with the reference monument. The final result of the RDD method is a plot of resultant cumulative displacement between monuments versus time determined across the entire length of the structure being analyzed.

Increasing (positive) RDD values indicate a monument is moving away from the reference monument and decreasing (negative) RDD values indicate a monument is moving toward the reference monument. Movements away from a reference monument can occur due to relative extension (i.e. tension, pulling away) or due to lateral (right or left) separation between the monuments. Movements toward the reference monument can occur due to relative compression, or due to thrust fault-type displacement between the monuments. RDD values that do not change indicate that no lateral or compressive movements are occurring between monuments.

The RDD method involves calculating two sets of differences data. The first set of data are the distances, calculated as the difference between coordinates of a selected reference monument typically at one end of the particular structure, and the successive monuments situated at progressively greater distances from the reference monument. Specifically, differences are calculated between respective northings (Y) values and eastings (X) values. Following determination of the differences in northings and eastings, there are three additional steps to the RDD method of analysis. The first step of the analysis involves computing the cumulative difference between the initial data set and successively more recent data sets for each monument. The second step involves calculating the resultant displacement (vector addition) of each data set based on the cumulative difference values of northings and eastings from step 2. The third and final step is to plot resultant displacement versus time to visually display resultant changes in distances between the reference monument and other in-line monuments.

We believe the RDD method provides more realistic results than the older transverse method and the vector method of determining lateral movements. The movements calculated from the transverse method are somewhat ‘artificial” because only movements occurring at right angles to the line between the stable reference points are detected. Because of the direct comparison between successive monuments, the RDD method will more readily detect movements within the structure itself.

The sign convention for the original transverse method is that negative displacements indicate relative downstream displacement and positive displacements indicate upstream displacement. For this sign convention, the assumed fixed reference point is situated left of the dam. The sign convention is opposite for the other two methods (vector and RDD) that have assumed fixed reference points situated right of the dam.

2.5.2 New Method of Double Differences (DD) to Determine Vertical Displacement

Since the 2006 surveillance report (Nelson and Volpe, 2007) we analyzed survey data using a methodology referred to as Double Differences to monitor vertical displacement (i.e. changes in elevations) specifically related to heave or settlement by comparing the elevation of each monument to a reference monument. The DD method is useful for filtering out jumps in plots due to periodic changes in datum. This is possible because datum changes result in a uniform change in elevation across the structure which is filtered out by the method of double differences, as described in the next paragraph. Alternately, because relative heave or settlement only affects a portion of the structure (thus is not uniform across the structure) the double differences result in refinement of vertical displacements so that subtle movements can be detected across the structure. This method allows us to detect progressive deformation of the embankment if it were occurring.

Similar to the RDD method for lateral displacement, we calculate and plot cumulative differences between a selected reference monument and successive monuments situated at progressively greater distances from the reference monument. We then plot the calculated cumulative changes in elevation values versus time relative to the reference monument. The difference between RDD and DD methods is that for the vertical displacement (DD) we don’t calculate resultant displacement as we did for the lateral Northings and Eastings data (RDD). The DD method allows for detection of upward thrusting (heave) or down-dropping movements (settlement) across the entire structure relative to a locally fixed reference point, which for Anderson Dam is the right abutment monument No. 16.

Since July 1988 the District has used Global Positioning Satellite (GPS) methods to survey new crest monuments installed at Anderson Dam after the 1986-87 dam raise.

2.5.3 Dam Crest and Abutment Monuments

The crest monuments generally alternate between the downstream edge and upstream edge of the crest. Data plots have been grouped as either "upstream (U/S) edge" or "downstream (D/S) edge". The location of the surface monuments are shown in Figure 1.

As noted in a previous report (Nelson and Volpe, 2003), because mon #31 was destroyed during the 2003/2004 boat ramp construction, the new left abutment endpoint is mon #30.

2.5.4 Spillway Training Wall Monuments

Three survey monuments are located at the top of the spillway training walls, two on a wall on the left side of the spillway ogee (#14 and #15), and one on a wall on the right side of the ogee (#13), as shown in Figure 1. It should be noted that mon. #13, on the right spillway wall, has not been monitored since October 2001 because of difficult access for the surveyors. Also, it recently came to our attention that previous spillway training wall horizontal and vertical survey results may be questionable. Access to the training wall monuments are somewhat blocked by chain link fences that are situated directly over the monuments making it difficult to survey the monuments (see Nelson and Volpe, 2004 for more information).

Because the spillway training wall survey monument data may be questionable, we decided to not provide data plots from previous reports.

3.0 SURVEILLANCE DATA

3.1 Annual Reservoir Fluctuation

Shown in Figure 5 are reservoir fluctuation from 2007 through most of calendar year 2008 (gray shading). Boat ramp construction and below normal rainfall from 2001 to 2004 contributed to lower reservoir levels prior to the 2004-05 winter. During the two years ending in 2008 and 2009 Anderson reservoir experienced relatively uniform rise-and-fall in water levels due to a fair amount of rainfall early in the two respective winters.

Anderson Reservoir began 2007 at about el. 606.7 feet, or ~21 feet below spillway crest (el. 627.8). By the beginning of April 2007, the reservoir had experienced a slight lowering followed by gradual rise of ~8 feet to a maximum el. of 611.8 feet on April 1st. During this period the reservoir rose at a rate of approximately ~0.07ft/day. From April 2007 through December 2007 reservoir levels dropped approximately 13 feet at a rate of ~0.04 ft/day. During 2008 Anderson reservoir experienced a relatively uniform rise-and-fall in water levels, similar to reservoir excursions during 2007. Anderson Reservoir began 2008 at about el. 595.7 feet, or ~32 feet below spillway crest (el. 627.8). By early March 2008, the reservoir had gained about 17.6 feet and had reached its high elevation of the year of 613.3 feet on March 5th. During this period the reservoir rose at a rate of approximately ~0.27 ft/day. From March 2008 through early August 2008, reservoir levels dropped only 4.3 feet at a rate of ~0.03 ft/day. Between the first week in August through mid-November the reservoir releases averaged ~0.11 ft/day and the reservoir dropped from about el. 609 to 598 feet. The reservoir then remained fairly steady at about el. 598 feet through the remainder of the year.

The preponderance of rainfall for any given calendar year typically occurs during January through April/May. For the current reporting period rainfall was below normal (~16 inches cumulative rainfall) and thus there is much more muted reservoir response similar to the previous year as shown in Figure 5.

3.2 10-year Reservoir Fluctuation

Figure 6 shows the reservoir fluctuation over the last 10 years from January 1999 through most of calendar year 2008. This is the first time that we have plotted the most recent 10-yr reservoir history. As can be seen in Figure 6, a period of low reservoir levels from Jan 2001 to the end of 2004 coincides with the construction of the new boat ramp in the left abutment area which required a lower reservoir level. In addition, the boat ramp construction coincided with a period of slightly below normal rainfall.

A convenient way to look at statistical multi-year reservoir trends is to evaluate a probability of occurrence for reservoir levels during the last 10 year period. Figure 7 is a plot of Probability of Reservoir Exceedance from 1999 through 2008. As shown in Figure 7, during the referenced 10 year period the reservoir data covers a range in reservoir fluctuation of 66.2 feet between the high and low reservoir elevations of 628.5 ft (0.7 feet above spillway lip) and 562.3 ft, respectively. The approach to calculating this probability assessment is to start with the daily average reservoir level for the 10 year period and then arrange each day’s level from the highest to lowest ranking. Then, a simple probability of occurrence is computed for any assumed reservoir elevation by computing how many days of record were higher and lower than the given elevation. As shown in Figure 7, the mean reservoir level (50 percentile) during the most recent 10 year period of operation was el. 604.1 ft. Other reservoir levels of interest are summarized on Table 2.

3.3 Piezometers

Figure 8 shows both pneumatic and open well piezometric levels, reservoir levels, and monthly rainfall data for the most recent 10 year period from January 1999 through December 2008. Table 3 and the gray area of Figure 8 show data since our 2007 report (Nelson and Volpe, 2007).

Overall, the data indicates that fluctuations in piezometric levels show a very muted response to fluctuations in reservoir level. Pneumatic piezometers PPA-1 and PPA-2, located in the lower portion of the central clay core, consistently show minor variations in piezometric elevations under wide range in reservoir fluctuations. It should be noted that 3 data points from January 2007 through April 2007 collected from PPA-1 and PPA-2 were anomalously low and plot as “trough 1” and “trough 2” on Figure 8. We believe it is possible that these troughs represent systematic errors introduced by the field technician. Figure 8 also shows red lines that bridge the two troughs. These red lines represent our attempt to correct the systematic error by adding a numerical value of 10 to the field readings for both piezometers. This correction appears to adequately compensate for the apparent errors introduced to the data. The District has taken measures to ensure that the field technician is adequately trained in taking piezometer readings and recognizing spurious data.

As shown in Figure 8, since installation, open well OW-1 (located about 50 feet from the downstream toe of the dam) has consistently ranged between ~el. 403.7 feet and 406.6 feet, or ~10 feet to 13 feet below ground surface. For 2008, piezometric elevations in OW-1 were consistently ~406 feet, which corresponds to a depth of ~10 ½ feet below ground surface.

3.3.1 Preliminary Findings of New Vibrating Wire Piezometer Responses

Figures A-1 through A-31 in Appendix A are individual plots of piezometer and reservoir elevations versus time for each piezometer. The data presented in Appendix A are in the form of piezometric surface elevation (PSE) vs. time for each piezometer. The PSE is defined as the sum of the piezometer tip elevation (feet) and the hydraulic pressure head (feet). Figures B-1 through B-31 in Appendix B are cross plots of new vibrating wire piezometers showing piezometric response versus reservoir elevation for each piezometer. Two general trends in data are evident on the cross plots. First, when a particular piezometer does not respond to changes in reservoir elevation because it is somehow isolated from influences of the reservoir, the data plot as a relatively straight line (termed “flat line”). Second, when a piezometer measures an increase in piezometric response due to increased reservoir elevation, the data plots as a sloping line upward to the right on the cross plots indicating a direct connection between reservoir changes and piezometric response.

Section views in Figures 2 through 4 graphically depict the maximum response of the new VW piezometers in 2008. The maximum Anderson Reservoir elevation since installation of the VW piezometers was about 613 feet on April 9, 2008, which is about 14 feet below the spillway lip. Two piezometric surfaces are present at various locations; one surface shown as red double-dash line passes through the embankment and transition zones, and a second surface (blue double-dash line) passes through the in-place alluvium/colluvium and the foundation bedrock foundation. We expect these piezometric surfaces to be generally higher in the future when the reservoir approaches the spillway lip.

3.3.2 Preliminary Observations of New Piezometer Results

There are several interesting observations based on piezometer information to date. These are summarized below.

- Piezometers located within the upstream and downstream sections of the massive central clay core of the dam show that the hydraulic pressures being imposed by the dam are being safely dissipated by head losses through the core in a safe and effective manner. Based on the results from the 17 piezometers located within the U/S Zone 2 and D/S Zone 3 core sections (see Table 1) no significant variations in hydraulic head losses are obvious across the entire width or length of the dam.

    - Based on the results of the upstream transition zone piezometers, there is essentially no loss (dissipation) of reservoir head through the upstream rockfill shell and transition zone. In other words, the full reservoir hydrostatic head is acting along the upstream sloping face of the core.

    - There were two fundamentally different methods of installing the VW piezometers in the core. One is referred to as the “sand-pack” method where the piezometer tip is enveloped in a sand pack sandwiched between bentonite grout above and below. The second method is referred to as the “grout-in” method in which multiple piezometers (up to 4 at Anderson in boring DH 9-6) are connected to a PVC pipe, installed at the appropriate depth, and then grouted in such that there is a continuous column of grout from the bottom to the top of the hole. The grout-in method is new and considerably faster and easier to install than the older sand-pack method. Also, the new vibrating wire piezometers are specifically designed and manufactured to be grouted in place without a sand pack and fully respond to changes in surrounding pore pressures. Some engineers and geologist are skeptical of the new methods and consider the grout-in method to be controversial and unproven. It is significant that at Anderson Dam, at least to date, there does not appear to be any difference in the distribution of pore pressure in the core, regardless of the method of installation. At Anderson, 14 piezometers were installed using the grout-in method and the remaining 17 piezometers were installed using the “sand-pack” method.

- The majority of the foundation piezometers are measuring only a fraction of the total possible pressure head at various locations beneath the core of the dam. This supports the effectiveness of the foundation treatment during construction and the fact that the vast majority of the clay core rests on (is in direct contact with) either predominantly competent Franciscan Complex bedrock or semi-consolidated older alluvium/colluvium. The only major exception appears to be in the central core area near the maximum section adjacent to the original alignment of Coyote Creek. Foundation piezometers 72-9-9B (VW piezometer with a tip elev. = 382) and PPA-2 (pneumatic piezometer with a tip elev. = 437.8) are measuring a maximum PSE of 501.9’ and 507.8’, respectively. This corresponds to a hydraulic pressure head of 120’ and 70 feet, respectively, which is significantly lower than the maximum PSE of elev. 627.8. This is an area where seeps were encountered during constriction and may represent more permeable zones with the foundation bedrock.

- Four piezometers were installed within the downstream transition zone, including 72-9-7 and 72-9-8 in Section A-A (Figure 2), and 72-9-16 and 72-9-17 in Section B-B’ (Figure 3). These four piezometers are all measuring less than one foot of pressure head. These results indicate that the transition zone is effectively capturing the phreatic surface as it exits the downstream face of the core. These results further suggest that the downstream rockfill zone is essentially dry.

- Piezometers 72-9-28 and OW-1 are both located in the downstream foundation, with OW-1 actually located about 50 feet beyond the downstream toe very close to the maximum section. These two piezometers have a drop in maximum PSE value of about 4.7 feet over a horizontal distance of about 240 feet. This computes to a relatively low horizontal seepage gradient of about 0.02 (4.7’/240’) in the downstream toe area.

3.4 Spillway Underdrain Flow

Starting with this report we are only providing historic data plots covering the last 10 years (since ~ 1999). Spillway underdrain flow data was formerly collected using a flow meter. This form of data was last collected in 1998 when weirs No. 1 and No. 2 were constructed to replace the underdrain flow meter. Consequently, we no longer provide data plots of the former underdrain flow, but only plots of the weir discharge data. Figure 9 shows monthly rainfall and data from weirs No. 1 and No. 2 from April 2000 through November 2008.

During 2008, the combined flow from the weirs ranged from a low of 41 gpm (February 2008) to a high of 165 gpm measured May 2008.

3.5 Crest and Spillway Training Wall Monuments

For the current surveillance period, the monuments were surveyed on October 9, 2008.

The terrestrial survey performed at Anderson Dam is based on using conventional GPS techniques to establish current coordinates (northing and easting) for the local bench mark (Monument 393) used for the survey. This is accomplished by using the known coordinates of benchmarks located reasonably close (typically within 1 to 2 miles) to the site. The last date for which accurate county-wide GPS surveys were performed to establish the benchmark coordinates is referred to as an "epoch" date. The last such epoch date for the area around Anderson Dam was in 1991. A new epoch survey within the county was performed in 2004. During the intervening 13 years between epoch surveys, the computed average lateral shift for all dam monument was $\Delta N = 0.95$ ft and $\Delta E = 0.90$ ft. It is believed that a majority of the inferred movement is due to local tectonic movement associated with the San Andreas and Calaveras faults. In addition, there was an approximate 0.04 ft (0.48 in) apparent heave between the epoch surveys.

3.5.1 Resultant Horizontal Displacement (RDD) and Vertical Displacement (DD)

Table 5 summarizes recent horizontal (RDD) and vertical (DD) displacement data for the crest monuments.

Figure 10 is a plot of resultant horizontal data (RDD) of monuments located along the downstream edge relative to Mon. 16 since 1999 (last ~10 years). Figure 11 is a similar plot of the upstream edge of crest monuments relative to Mon. 16 for the same period of time. The shaded area in Figures 10 and 11 show data since the 2007 report (Nelson and Volpe, 2007).

Figures 12 and 13 are plots of vertical data (DD) relative to Mon. 16 of monuments located along the downstream edge and upstream edge, respectively.

The vertical and horizontal data presented in Figures 10 through 13, and Table 5, for the crest monuments, indicate minimal horizontal and vertical displacements (average of zero movement during the last year) have occurred during this reporting period. These minimal displacements appear to be random movements of the dam with no obvious trends.

4.0 SIGNIFICANT AND NOTEWORTHY SEISMICITY

Noteworthy earthquakes, defined as having approximate magnitudes less than 5.0 (ML) (the approximate District threshold for initiating dam inspections) occurred at 5 locations in the San Francisco Bay Area in the vicinity of the dam, during the reporting period from November 2006 through December 2008 (Figure 14) with the following date, magnitude, distance and direction from Anderson Dam:

1. ML 4.2 on July 2, 2007, 20 miles southeast.
2. ML 5.4 on October 30, 2007 (Alum Rock), 20 miles northwest.
3. ML 4.0 aftershock of the Alum Rock earthquake on October 31, 2007, 20 miles northwest
4. M_L 4.0 on December 21, 2008, 38 miles southeast.

In addition to showing the location of these 4 earthquakes, Figure 14 summarizes estimated ground accelerations using published attenuation relationships for all the Districts dams as a result of the Alum Rock earthquake on October 30, 2007 (local time, October 31, 2007 universal time). For Anderson Dam we estimate an acceleration of 0.04 g.

For the October 30, 2007 Alum Rock event, a post-earthquake inspection of Anderson Dam was completed by staff (J. Nelson) due to fact that earthquake magnitude and proximity to the dam triggered the District’s Post Earthquake Dam Assessment Program, which consists of a an earthquake of ML>5 with an epicenter closer than 20 miles from any District dam. For the Alum Rock event, the District performed a formal post-earthquake survey which revealed no damage.

5.0 ACCELEROMETERS

There are 6 accelerometers at the site (5 on the dam, and one on the left abutment knob) which are owned, maintained and monitored by USGS. As mentioned above, a noteworthy earthquake with magnitude 5.4 occurred on October 30, 2007 (local time; October 31, 2007 Universal time), about 20 miles northwest of Anderson Dam. The U.S.G.S. has named it the “October 31, 2007 Alum Rock” earthquake. Acceleration data from the U.S.G.S. accelerometers located on the crest and downstream face of Leroy Anderson Dam due to the Alum Rock earthquake are summarized below.

USGS National-Strong Motion Project
Preliminary Corrected Peak Ground Acceleration and Velocity and Pseudo-Spectral Acceleration Values for
October 31, 2007, Alum Rock, CA Earthquake (posted 10/31/2007; updated 11/30/2007)

Mw 5.4, 10/31/2007, 03:04 UTC, 10/30/2007, 08:04 PM PDT, 37.432 N, 121.776 W, 9.2 km depth, Regional Network ID# nc40204628

Sta	Inst	Inst	State: City; Recorder Locatio	Owner	Lat	Lon	Dist	Az	Ch	Sensor	Orient	PGA		PGV	PSA at:		
No	type	S/N			deg	deg	km	deg	No	type	deg	cm/s/s	"g"	cm/s	0.3 s	1.0 s	3.0 s
1652	K2	1357	CA:Anderson Dam	USGS	37.166	-121.630	32.2	156									
			Toe						1	FBA-23	333	18.4	0.02	1.73	6.32	2.05	0.777
			Toe						2	FBA-23	UP	-19.1	-0.02	1.89	4.60	3.18	0.428
			Toe						3	FBA-23	63	-28.4	-0.03	-2.93	4.59	4.83	1.340
			Mid-dam, center						4	FBA-11	333	26.8	0.03	-1.73	5.41	1.86	0.785
			Mid-dam, center						5	FBA-11	63	-30.7	-0.03	3.57	7.66	5.79	1.360
			Mid-dam, right						6	FBA-2g	63	-26.0	-0.03	3.47	6.34	6.36	1.420
			Right crest						7	FBA-23	333	-43.2	-0.04	2.61	11.20	2.06	0.757
			Right crest						8	FBA-23	UP	-30.1	-0.03	2.40	8.96	2.24	0.463
			Right crest						9	FBA-23	63	-47.0	-0.05	4.88	19.50	7.89	1.530
			Center crest						10	FBA-23	333	-36.4	-0.04	2.74	11.80	2.46	0.740
			Center crest						11	FBA-23	UP	-35.1	-0.04	3.06	16.10	2.93	0.469
			Center crest						12	FBA-23	63	62.0	0.06	6.61	21.20	7.47	1.450

Table 6 – USGS Acceleration Data from October 31, 2007 Alum Rock Earthquake

As noted by gray shading in Table 6, the highest accelerations ranged between 0.05 g at the right crest and 0.06 g at the center crest of the dam. In addition to the accelerometers on the dam face and crest, the U.S.G.S. recently installed a strong motion accelerometer in bedrock about 1000 feet east of the dam that is tied to the U.S.G.S. National Strong Motion Project and reports rapid earthquake information to the internet. This instrument recorded a Peak Ground Acceleration of 0.02 g during the Alum Rock earthquake.

A new strong motion accelerometer was recently installed on the crest of the dam in association with the dam instrumentation project. This new instrument will be maintained by the District.

6.0 VISUAL INSPECTIONS AND MAINTENANCE ISSUES

The following significant inspections were performed during the period of this report include:

1. On August 28, 2006, District staff (S. Wallis, R. Volpe, D. Hook, Mooers, J. Aguilera, J. Nelson, L. Wong, and B. Cane) and FERC Engineers Bart O’Keeffe and Wesley Doubleday performed an annual FERC inspection of Anderson Dam and appurtenant structures.

2. On August 31, 2006, District staff (S. Wallis, M. Mooers, and J. Nelson) and DSOD field engineer Aspet Ordoubigian performed an annual DSOD site inspection.
3. On September 19, 2006 District staff (R. Volpe, M. Mooers, and J. Nelson) and DSOD personnel including field engineer Aspet Ordoubigian, engineering geologist Jim Lessman, and design engineer Chris Dorsey observed drilling of DIP borings and installation of new instruments.
4. From August 2006 through December 2006 District staff (R. Volpe, Mooers, and J. Nelson) visited site numerous times to observe various aspects of DIP drilling.
5. On May 15, 2007 District staff (R. Volpe, D. Hook, M. Mooers, S. Wallis, & J. Nelson) and FERC core members (Abbas Orumchian, Ken King, Steve Verigen, Carol Buckles, Bill Rettburg, and Bill Cole) performed a pre-Potential Failure Mode Analysis site visit of Anderson Dam and appurtenant structures.
6. On May 17, 2007 District staff (R. Volpe, D. Hook, M. Mooers, S. Wallis, Joseph Aguilera, & J. Nelson) and FERC core members (Bart O'Keeffe, Abbas Orumchian, Carol Buckles, Bill Rettburg, and Bill Cole) performed a combined annual FERC inspection and 2007 Part 12 safety site visit of Anderson Dam and appurtenant structures.
7. On October 25, 2007 District staff (R. Volpe, M. Mooers, D. Hook, N. Merrill, D. Honda, J. Jenkins, T. Pieracci, and J. Nelson) along with seismic stability evaluation (SSE) consultant Geomatrix personnel (F. Makdisi, M. Ryan, and J. Phalen) and Tabur Drilling contractor (driller Tom Scott) performed site visit to assess proposed future drilling sites.
8. As mentioned above, on October 31, 2007 District staff (J. Nelson) performed a post-earthquake inspection of the dam following the Alum Rock earthquake that occurred on the Calaveras fault on October 30, 2007). No adverse conditions were observed.
9. On November 11, 2007 District staff (R. Volpe, M. Mooers, N. Merrill, D. Honda, and J. Nelson) along with seismic stability evaluation (SSE) consultant Geomatrix personnel and Taber Drilling contractor performed site visit to evaluate access issues related to future drilling sites.
10. A November 14, 2007, fall inspection of Anderson Dam and appurtenant facilities by DSOD field engineer Aspet Ordoubigian, with several District employees (D. Hook, J. Aguilera, J. Bozzo, M. Mooers, and S. Wallis).
11. On May 6, 2008 District staff (D. Hook, B. Baker, S. Wallis, J. Bozzo, & J. Nelson) and FERC Engineers Bart O'Keeffe and Chris Wang performed an annual FERC inspection of Anderson Dam and appurtenant structures.

6.1 Other District Inspections

This additional safety inspection by District staff focused on maintenance and monitoring issues.

1. On February 28, 2007 staff of the Dam Safety Section of the District's Infrastructure Planning Unit (R.L. Volpe, J. Nelson, and H. Haase) along with other District personnel was present at Anderson Dam for orientation of the Post-Earthquake Dam Assessment Program (PEDAP). The purpose of the PEDAP is to deploy personnel to make preliminary field assessment of dam safety conditions immediately following a significant earthquake near the respective dam facility.
2. As mentioned above, on October 31, 2007 District staff (J. Nelson) performed a post-earthquake inspection of the dam following the Alum Rock earthquake that occurred on the Calaveras fault on October 30, 2007). No adverse conditions were observed.
3. On September 17, 18, 23, and 25, 2008 District Senior Engineering Geologist J. Nelson and Assistant Engineering Geologist Brett Baker performed geologic field observation of the Boat Ramp repair work performed by the County of Santa Clara Parks and Recreation. A copy of a memo by J. Nelson dated 11-4-08 that describes pertinent geologic field observation during the landslide repair is presented in Appendix C. A summary of pertinent information from this memo is presented in section *8.1 September 2008 Repair of the Boat Ramp Landslide*.

7.0 SURVEILLANCE PROGRAM

The District will continue with the current operating procedures and scheduled surveillance plans. Pneumatic and open well piezometers will be read monthly, crest and spillway training wall monuments will be surveyed annually, and spillway underdrain flows will be measured at the two weirs at least monthly. In addition, site inspections and monument surveys will be conducted after a significant earthquake or other potentially disruptive activity. The instruments are in good working order, so we do not anticipate replacement or repair work in 2009.

A significant upgrade in instrumentation was accomplished at the dam in calendar year 2006. In total, 31 new vibrating piezometers were installed within various zones of the dam and foundation. Although data are being collected, the automated data acquisition system (ADAS) is still being tested. Data from all instruments on ADAS are being automatically collected at about 10 minute intervals and are being saved by a mass data storage system on site. This frequency rate is significantly higher than necessary; however, it is considered appropriate to evaluate consistency, variability, magnitude of scatter, and various bandwidth issues regarding the ADAS system. All instruments are polled every six hours and that data are sent via satellite to District headquarters once per day. Various plotting methods and types are being evaluated by the dam safety staff and one will be selected for use in presenting monthly summary reports to District management. The 2009 annual report will incorporate new plotting reports developed by the District.

8.0 OTHER INFORMATION

8.1 September 2008 Repair of the Boat Ramp Landslide

The following background information and conclusions regarding our geologic observations during the recent repair of the Boat Ramp by Santa Clara County Parks and Recreation are taken from the 11-4-08 memo by J. Nelson presented in Appendix C:

Widening and upgrades to the original boat ramp were completed by Santa Clara County Parks and Recreation by late 2003 to early 2004 under a permit issued by the District. During an annual inspection with the Federal Energy Regulatory Commission (FERC) on July 8, 2003, District and FERC personnel observed some cracking of the hillside directly upslope of the boat ramp. Mapping by J. Nelson on July 15, 2003 indicated that grading of the slope adjacent to the boat ramp had been performed by the County as a result of the boat ramp widening. The Boat Ramp Landslide was first noticed approximately 1 year later during the annual FERC inspection of July 2004. J. Nelson mapped the landslide on July 18, 2004 and concluded that the landslide likely involved failure of a fill slope added during boat ramp construction in an email dated July 20, 2004. The County completed their first repair of the Boat Ramp Landslide by November 2004. A second reactivation of the Boat Ramp landslide was noticed by fall 2006, which is the focus of the most recent repair work completed in late 2008.

We made field observations to observe landslide repair work of the Boat Ramp Landslide under the direction of Santa Clara County Parks and Recreation on September 17, 18, 23 and 25, 2008. On September 25, 2008, we observed landslide shear surfaces in a keyway trench wall near the upslope head of the Boat Ramp Landslide that appeared to be basal shear surfaces of individual coalescing landslides, which appear to override the upper portion of the active Boat Ramp Landslide. It was decided to leave the upper landslides in-place because it was beyond the scope of the County's current effort to remove landslides other than the Boat Ramp Landslide.

Consequently, there is a remote possibility that future landsliding could occur in the vicinity of the Boat Ramp Landslide due to movement on the secondary coalescing landslides, which are likely a part of the much larger Landslide “B_2” previously mapped by former District geologist J. Scott (1977). It is significant that during our September 25, 2008 site visit we observed inclinometer casing SI-2 in the headwall of the keyway trench that appeared to have been bent due to active movement of Landslide “B_2”. This substantiates previous landslide activity in the vicinity of the Boat Ramp Landslide, especially during the early 1970s (Scott, 1977). It appears likely that the repaired Boat Ramp Landslide may act as a buttress to the secondary coalescing landslides and thus minimize the possibility that new landsliding will occur in the vicinity of the repaired Boat Ramp Landslide. Any future slope instability in the vicinity of the Boat Ramp Landslide will not likely affect the dam itself, but a reactivated landslide has the potential to adversely affect the District’s outlet facilities, such as the utility trench containing the air vent and hydraulic lines for the outlet. The District notified Santa Clara County that based on the findings of the 11-4-08 memo the County would be responsible for any future repairs of landsliding in the Boat Ramp Landslide.

8.2 Recent Engineering Analyses

To address FERC’s request to investigate the presence of the upstream and downstream transition zones (TZs) in the dam, the District retained Fugro West to oversee installation of new surveillance instrumentation during the 2006/2007 DIP field investigation. As part of the contract, Fugro West performed a drilling, sampling and testing program to generally define the presence of the TZs (Fugro, 2007). The DIP field investigation confirmed that the transition zones are located between the impervious core and the upstream and downstream rockfill zones and consist of intermediate-graded materials between these two units (core and rockfill zones). Additional work to refine the geotechnical aspects of the transition zones is currently being performed by GEI Consultants and their results will be separately published in early 2009.

On December 29, 2008 the District submitted a copy of the AMEC Geomatrix Preliminary Seismic Stability Evaluation of Leroy Anderson Dam (AMEC Geomatrix, 2008) to both DSOD and FERC informing them of its findings and the District’s resulting action to implement an operation restriction to keep the reservoir below elevation 617.2 ft NAVD. This provides an added ~10 feet of freeboard for a total reservoir freeboard of ~30 feet. Based on the presence of potentially liquefiable soils found in the foundation and the urban population immediately downstream of the dam, DSOD requires that the District provide an additional 10 feet to the proposed operating restriction. This provides a reservoir operating restriction of ~20 feet and a total reservoir freeboard of ~40 feet. Consequently, the District will keep the reservoir below elevation 607.2 ft NAVD. This will restrict Anderson reservoir to a capacity of 66,723 acre-feet or 73%.

9.0 CONCLUSIONS

We conclude that Anderson Dam shows a normal response to its environment, aging process, and external events. The District will continue with the current monitoring program and safety inspections and will keep DSOD informed of any significant changes pertaining to the surveillance or performance of Leroy Anderson Dam.

As noted above, 3 data points from January 2007 through April 2007 collected from PPA-1 and PPA-2 were anomalously low and plot as “trough 1” and “trough 2” on Figure 8. We believe that these represent systematic errors introduced by the field technician. Figure 8 also shows red lines that bridge the two troughs. These red lines represent our attempt to correct the systematic error by adding a numerical value of 10 to the field readings for both piezometers. This correction appears to adequately compensate for the apparent errors introduced to the data. We will keep DSOD apprised of any unusual trends in the piezometer data. The District has taken measures to ensure that the field technician is adequately trained in taking piezometer readings and recognizing spurious data.

Our review of the monitoring data presented herein does not indicate unusual or abnormal changes in the monitoring data during the subject reporting period. Our review of the surveillance data, and our periodic safety inspections, indicate that Anderson Dam appears to show normal responses to the environment, aging process, and external events.

By the end of 2009, the District plans to implement a formal process for monthly analysis of surveillance data that will be reported to District management.

10.0 REFERENCES CITED

Abrahamson, N.A. and Silva, W.J., 1997, Empirical response spectral attenuation relations for shallow crustal earthquakes: in Seismological Society of America, Seismological Research Letters, Vol. 68, No. 1, January/February 1997, pp. 128-153.

AMEC Geomatrix, 2008, Technical Memorandum 4 (TM-4), Preliminary Stability Evaluation of Anderson Dam, Seismic Stability Evaluation of DIP Phase I Dams, Agreement No. A3087A, File 4073, Santa Clara County, California, dated December 17, 2008, 11 p.

International Conference of Building Officials, 1998, Maps of known active fault near-source zones in California and adjacent portions of Nevada: ICBO, scale 1 in = 4 km.

Frame, Philip A., 2001, Engineering Geologic Report for Anderson Reservoir Spillway Falls Area, July, 9 p.

Fugro West, Inc., 2007, Geotechnical Support Services Project (GSSP) Dam Instrumentation Project (DIP) – Phase 1 (Volume 1 of 6) Field and Laboratory Data Report for Anderson Dam, prepared for Santa Clara Valley Water District,

GEI Consultants, Inc., 2001, Fourth Quinquennial Safety Inspection, Leroy Anderson Dam and Hydroelectric Facility, FERC Project 5737, State Dam No. 72-009, unpublished consultant’s report on file at the Santa Clara Valley Water District, San Jose, California, 56 p. (FERC Part 12 Safety Inspection).

GEI Consultants, Inc., 2007a, Fifth Quinquennial Safety Inspection, Leroy Anderson Dam and Hydroelectric Facility, FERC Project 5737, State Dam No. 72-009, unpublished consultant’s report on file at the Santa Clara Valley Water District, San Jose, California, 63 p. + appendices (FERC Part 12 Safety Inspection).

GEI Consultants, Inc., 2007b, Supporting Technical Information Document (STID), Leroy Anderson Dam and Hydroelectric Facility, FERC Project 5737, State Dam No. 72-009, unpublished consultant’s report on file at the Santa Clara Valley Water District, San Jose, California, 32 p.

Nelson, J.L. and Kahn, M., March 9, 1999, Dam Surveillance Evaluation Report, Leroy Anderson Dam, 1998 Annual Report, Santa Clara Valley Water District unpublished report, 8 p.

Nelson, J.L. and Kahn, M., January 18, 2000, Dam Surveillance Evaluation Report, Leroy Anderson Dam, 1998-1999 Annual Report, Santa Clara Valley Water District unpublished report, 8 p.

Nelson, J.L. and Volpe, R.L., 2001, Surveillance Report, Leroy Anderson Dam No. 72-9, Santa Clara County, 2000 Summary Report and Analysis, Santa Clara Valley Water District unpublished report, 9 p.

Nelson, J.L. and Volpe, R.L., 2002, Preliminary Instrumentation Design of Ten Dams Owned and Operated by Santa Clara Valley Water District, Santa Clara Valley Water District unpublished report, 22 p.

Nelson, J.L. and Mooers, M.R., 2003, First Interim Surveillance Report, Jan 2001-Nov 2002, Leroy Anderson Dam No. 72-9, Santa Clara County, Santa Clara Valley Water District unpub. report, 8 p.

Nelson, J.L. and Mooers, M.R., 2004, Second Interim Surveillance Report, Nov 2002-Oct 2004, Leroy Anderson Dam No. 72-9, Santa Clara County, Santa Clara Valley Water District unpub. report, 9 p.

Nelson, J.L. and Volpe, R.L., 2007, Second Summary Surveillance Report, October 2004 - December 2006, Leroy Anderson Dam No. 72-9, Santa Clara County, Santa Clara Valley Water District unpub. Report, 15 p.

Northern California Earthquake Data Center (December2000), http://quake.geo.berkeley.edu/cgi-bin/catalog-search.y2K.pl.

Petersen, M., Toppozada, T., Cao, T., Cramer, C., Reichle, M., Maher, M., and Atchison, L., 1998, Determining distances from faults within and bordering the State of California for the 1997 Uniform Building Code: in International Conference of Building Officials 1998, Maps of Known Active Fault Near-Source Zones in California and Adjacent Portions of Nevada, pp. ix-xvii

Petersen, M.D., Bryant, W.A., Cramer, C.H., Cao, T., and Reichle, M.S., 1996, Probabilistic seismic hazard assessment for the State of California: Department of Conservation Division of Mines and Geology Open File Report 96-08.

Tepel, R.E, January 10, 1997, Leroy Anderson Dam, No. 72-9, Santa Clara County, Interim Summary Report and Analysis of Surveillance Data, Santa Clara Valley Water District unpublished report, 4 p.

Tepel, R.E, December 31, 1997, Leroy Anderson Dam, No. 72-9, Santa Clara County, Annual Summary Report and Analysis of Surveillance Data, Santa Clara Valley Water District unpublished report, 6 p.

United States Geological Survey (December 2000), National Strong-Motion Program, http://agram.wr.usgs.gov.

Volpe, R. L. & Associates, Inc., 1997, 1996 FERC Inspection and Safety Review, Leroy Anderson Dam and Hydroelectric Facility, unpublished consultant's report on file at the Santa Clara Valley Water District, San Jose, California, 66 p.

Wahler Associates, 1986, Inspection and Safety Review, Leroy Anderson Dam, unpublished consultant's report on file at the Santa Clara Valley Water District, San Jose, California, 42 p.

Wahler Associates, 1991, Safety Inspection of Anderson Dam and Hydroelectric Facility, unpublished consultant's report on file at the Santa Clara Valley Water District, San Jose, California, 44 p.

Working Group on Northern California Earthquake Potential, 1996, Database of potential sources for earthquakes larger than magnitude 6 in Northern California: U.S. Geological Survey Open File Report 96-705, 40 p.

Working Group on California Earthquake Probabilities, 1999, Earthquake probabilities in the San Francisco Bay region: 2000 to 2030 – a summary of findings: California: U.S. Geological Survey Open File Report 99-517, Internet online version 1.0, 36 p.

Table 1
Locations of Vibrating Wire Piezometers
Leroy Anderson Dam (No. 72-9)

Embankment Piezos

Downstream Core Zone 3	Tip Elev. (ft)	Surface Elev. (ft)
72-9-02*	480	647
72-9-03*	531	647
72-9-04*	580	647
72-9-05	484	631
72-9-10*	430	647
72-9-11*	480	647
72-9-12*	530	647
72-9-13*	580	647
72-9-17	421	583
72-9-20	550	647
72-9-22*	450	647
72-9-23*	500	647
72-9-24*	550	647
72-9-26	550	647
72-9-29*	444	613
72-9-30*	490	613

Upstream Core Zone 2	Tip Elev. (ft)	Surface Elev. (ft)
72-9-14	470.0	630.0

Transition Zone

Downstream	Tip Elev. (ft)	Surface Elev. (ft)
72-9-07	557	618
72-9-08	518	601
72-9-16*	539	613

Upstream	Tip Elev. (ft)	Surface Elev. (ft)
72-9-06	587.0	631
72-9-15	587.0	630.0

Bedrock Foundation

Foundation	Tip Elev. (ft)	Surface Elev. (ft)
72-9-01	453	647
72-9-9B	382	547
72-9-18	580	647
72-9-19	516	647
72-9-21	400	647
72-9-25	500	647
72-9-27	585	647

Alluvial/Colluvial Foundation

Foundation	Tip Elev. (ft)	Surface Elev. (ft)
72-9-28	405	485.0
72-9-31*	600	647.0

Note:

1) * = piezometer installed using grout-in methods (see text)
2) all other piezometer installed using sand-pack methods (see text)

Table 2. Probability of Anderson Reservoir Exceedance, 1999-2008

Leroy Anderson Dam (No. 72-9)

Percentage of Time Reservoir is Above Given Elevation, %	Reservoir Elevation, ft (NAVD 88 datum)
90	580.2
80	585.9
70	592.6
60	599.1
50	604.1
40	607.0
30	610.7
20	613.9
10	621.9

TABLE 3
Recent Piezometric Data
Leroy Anderson Dam (No. 72-9)

Date	Reservoir Level (ft)	PPA-1	PPA-2	OW-1	Monthly* Rainfall (in)
		Piezometric Surface Elevation (ft)			
12/20/06	606.84	577.52	505.00	406.19	2.20
1/17/07	606.00	545.36	477.76	406.10	0.63
2/15/07	607.40	NR	NR	NR	4.09
3/12/07	607.70	547.88	479.40	406.19	0.43
4/17/07	611.60	548.34	481.92	406.00	1.02
5/21/07	610.70	577.45	505.95	405.82	0.04
6/14/07	609.40	576.64	504.74	405.85	0.00
7/18/07	607.60	575.37	502.71	406.10	0.00
8/14/07	606.80	577.40	500.86	405.87	0.00
9/18/07	605.90	577.40	504.10	405.88	0.43
10/17/07	605.20	575.14	501.79	405.89	0.59
11/15/07	604.80	576.30	502.53	405.98	0.98
12/15/07	NR	NR	NR	NR	1.46
1/15/08	597.20	575.26	502.02	405.94	9.21
2/25/08	606.50	579.30	489.31	406.24	2.83
3/20/08	613.10	578.37	503.40	406.10	0.16
4/15/08	613.00	577.91	503.87	405.05	0.04
5/6/08	612.70	NR	NR	NR	0.00
5/15/08	612.50	578.03	504.10	405.94	0.00
6/16/08	611.70	578.58	500.89	405.81	0.00
7/22/08	609.70	578.84	505.48	NR	0.00
8/13/08	608.30	578.88	507.79	405.78	0.00
9/17/08	603.40	578.37	503.40	405.84	0.00
10/20/08	600.30	578.03	503.64	405.80	0.28
11/13/08	598.50	577.47	498.67	405.78	1.69
12/17/08	598.00	577.36	497.63	405.59	0.47

Notes:
1) Piezometer data is Piezometric Surface Elevation (PSE in feet)
2) PSE = pressure head (ft) + elevation head (ft)
3) basis of elevations is NAVD 1988 - values in this table are 2.8 feet higher than NGVD 1929
4) NR = no readings collected
5) OW-1 installed 8/5/03

TABLE 4

Recent Weir Discharge Data – Spillway Underdrains

Leroy Anderson Dam (No. 72-9)

Date	Reservoir	Underdrain	flow (gpm)	Total flow
12/20/2006	606.84	103.00	9.43	112.43
1/17/2007	606.00	118.00	9.43	127.43
2/15/2007	607.40	NR	NR	NR
3/12/2007	607.70	88.90	6.29	95.19
4/17/2007	611.60	134.00	16.60	150.60
5/21/2007	610.70	126.00	54.30	180.30
6/14/2007	609.40	142.00	50.30	192.30
7/18/2007	607.60	150.00	23.30	173.30
8/14/2007	606.80	150.00	23.30	173.30
9/18/2007	605.90	134.00	38.60	172.60
10/17/2007	605.20	118.00	38.60	156.60
* 10/31/2007	605.00	96.10	6.29	102.39
11/15/2007	604.80	126.00	46.20	172.20
1/15/2008	597.00	46.20	6.29	52.49
2/25/2008	606.50	31.90	9.43	41.33
3/20/2008	613.10	142.00	29.20	171.20
4/15/2008	613.00	142.00	29.20	171.20
+ 5/6/2008	612.70	126.00	29.20	155.20
5/15/2008	612.50	142.00	23.30	165.30
6/16/2008	611.70	134.00	16.60	150.60
7/22/2008	609.70	134.00	12.60	146.60
8/13/2008	608.30	111.00	12.60	123.60
9/17/2008	603.40	65.10	12.60	77.70
10/20/2008	600.30	70.90	4.94	75.84
11/13/2008	598.50	46.20	6.29	52.49
12/17/2008	598.00	46.20	4.94	51.14

Notes: 1) Weir No. 1 collects flow from the central portion of spillway
2) Weir No. 2 collects flow from the left side of the spillway
* = reading after Alum Rock Earthquake 10/30/07
+ = annual FERC inspection

TABLE 5
Vertical (DD) and Resultant (RDD) Displacement Relative to Mon. 16 - Crest Monuments
Leroy Anderson Dam (No. 72-9)

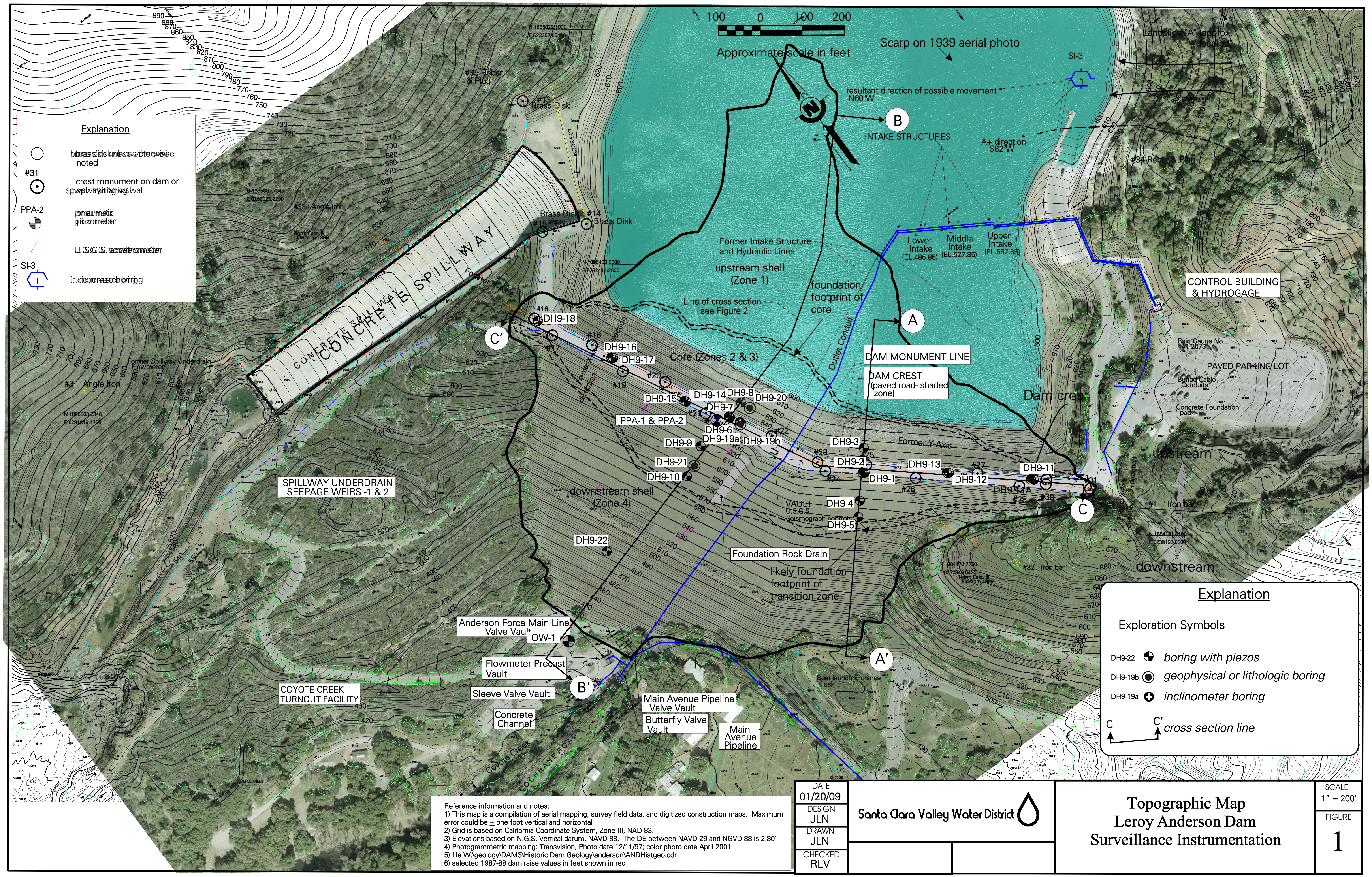
Date	Dam Crest Monument Vertical Displacement Relative to Mon. 16 (feet) (since 1988)														
	16 & 17	16 & 18	16 & 19	16 & 20	16 & 21	16 & 22	16 & 23	16 & 24	16 & 25	16 & 26	16 & 27	16 & 28	16 & 29	16 & 30	16 & 31
7/19/1988	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10/24/1989	-0.05	-0.03	-0.14	-0.08	-0.16	-0.09	-0.07	-0.17	-0.05	-0.06	-0.02	0.00	0.01	0.03	0.00
10/28/1990	-0.18	-0.17	-0.29	-0.21	-0.32	-0.24	-0.21	-0.32	-0.18	-0.16	-0.11	-0.09	-0.07	-0.06	-0.06
6/7/1991	-0.08	-0.08	-0.20	-0.15	-0.25	-0.20	-0.16	-0.27	-0.13	-0.12	-0.06	-0.02	-0.01	0.01	-0.03
1/8/1992	-0.08	-0.08	-0.22	-0.16	-0.26	-0.21	-0.16	-0.27	-0.12	-0.11	-0.06	-0.02	-0.01	0.03	0.01
1/27/1993	-0.09	-0.10	-0.26	-0.20	-0.31	-0.25	-0.25	-0.37	-0.23	-0.21	-0.14	-0.10	-0.10	-0.09	-0.11
11/1/1994	-0.09	-0.09	-0.25	-0.20	-0.31	-0.26	-0.24	-0.36	-0.21	-0.18	-0.12	-0.07	-0.06	-0.04	-0.07
12/5/1994	-0.09	-0.09	-0.26	-0.20	-0.32	-0.27	-0.21	-0.33	-0.17	-0.16	-0.09	-0.05	-0.03	-0.01	-0.04
1/4/1996	-0.08	-0.06	-0.21	-0.14	-0.25	-0.20	-0.15	-0.27	-0.10	-0.08	-0.02	0.01	0.02	0.03	0.03
5/22/1996	-0.08	-0.05	-0.21	-0.16	-0.28	-0.25	-0.20	-0.32	-0.15	-0.13	-0.06	-0.02	-0.02	0.00	-0.03
1/29/1997	-0.09	-0.09	-0.26	-0.20	-0.33	-0.28	-0.23	-0.36	-0.19	-0.16	-0.10	-0.05	-0.04	-0.02	-0.04
12/11/1998	-0.09	-0.09	-0.27	-0.20	-0.34	-0.29	-0.23	-0.36	-0.19	-0.16	-0.09	-0.05	-0.03	-0.02	-0.03
12/3/1999	-0.09	-0.08	-0.26	-0.20	-0.33	-0.29	-0.23	-0.36	-0.18	-0.15	-0.09	-0.04	-0.02	0.00	-0.02
11/28/2000	-0.09	-0.09	-0.27	-0.21	-0.34	-0.30	-0.25	-0.37	-0.20	-0.16	-0.10	-0.05	-0.03	-0.01	-0.02
10/18/2001	-0.09	-0.10	-0.28	-0.21	-0.34	-0.30	-0.25	-0.37	-0.19	-0.16	-0.09	-0.04	-0.03	-0.01	-0.02
10/15/2002	-0.09	-0.10	-0.28	-0.23	-0.36	-0.32	-0.25	-0.38	-0.21	-0.16	-0.10	-0.04	-0.02	0.00	-0.02
11/4/2003	-0.08	-0.10	-0.29	-0.23	-0.37	-0.32	-0.25	-0.38	-0.20	-0.16	-0.09	-0.04	-0.02	0.00	NR
10/15/2004	-0.09	-0.10	-0.29	-0.23	-0.37	-0.32	-0.26	-0.38	-0.20	-0.17	-0.09	-0.04	-0.02	0.01	NR
11/1/2005	-0.09	-0.09	-0.29	-0.22	-0.37	-0.32	-0.26	-0.39	-0.21	-0.17	-0.09	-0.04	-0.02	0.00	NR
10/31/2006	-0.07	-0.08	-0.28	-0.21	-0.36	-0.31	-0.25	-0.38	-0.20	-0.16	-0.09	-0.03	-0.01	0.01	NR
11/7/2007	-0.07	-0.08	-0.27	-0.21	-0.36	-0.31	-0.25	-0.38	-0.20	-0.15	-0.08	-0.03	-0.01	0.01	NR
10/9/2008	-0.06	-0.07	-0.27	-0.20	-0.35	-0.30	-0.24	-0.37	-0.19	-0.14	-0.07	-0.02	0.00	0.02	NR
change in disp.	0.00	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	NR
11/07 to 10/08			Average change since last survey in ft =				0.01	or 0.0"							

TABLE 5
Vertical (DD) and Resultant (RDD) Displacement Relative to Mon. 16 - Crest Monuments
Leroy Anderson Dam (No. 72-9)

Date	Monument Resultant Vector Displacement (feet)														
	16 & 17	16 & 18	16 & 19	16 & 20	16 & 21	16 & 22	16 & 23	16 & 24	16 & 25	16 & 26	16 & 27	16 & 28	16 & 29	16 & 30	16 & 31
7/19/1988	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10/24/1989	0.04	0.04	0.04	0.06	0.03	0.05	0.02	0.06	0.04	0.04	0.05	0.05	0.06	0.06	0.07
10/28/1990	0.03	0.04	0.04	0.05	0.04	0.09	0.08	0.08	0.10	0.05	0.08	0.04	0.05	0.04	0.03
6/7/1991	0.04	0.08	0.03	0.06	0.05	0.07	0.08	0.08	0.09	0.05	0.08	0.04	0.04	0.03	0.02
1/8/1992	0.04	0.06	0.03	0.07	0.01	0.06	0.05	0.07	0.08	0.04	0.07	0.04	0.04	0.02	0.01
1/27/1993	0.03	0.06	0.03	0.07	0.01	0.07	0.06	0.08	0.09	0.05	0.08	0.04	0.04	0.03	0.03
11/1/1994	0.04	0.05	0.09	0.03	0.10	0.02	0.08	0.12	0.07	0.04	0.06	0.01	0.03	0.02	0.02
12/5/1994	0.04	0.05	0.08	0.05	0.08	0.02	0.07	0.12	0.06	0.04	0.06	0.01	0.03	0.01	0.00
1/4/1996	0.06	0.06	0.13	0.06	0.13	0.04	0.11	0.15	0.06	0.06	0.05	0.02	0.01	0.01	0.02
5/22/1996	0.03	0.02	0.14	0.06	0.15	0.05	0.13	0.19	0.04	0.07	0.02	0.03	0.01	0.02	0.03
1/29/1997	0.05	0.03	0.13	0.06	0.16	0.03	0.12	0.15	0.06	0.04	0.06	0.03	0.05	0.04	0.05
12/11/1998	0.08	0.07	0.16	0.09	0.18	0.05	0.12	0.18	0.06	0.05	0.06	0.01	0.03	0.01	0.03
12/3/1999	0.06	0.04	0.15	0.07	0.17	0.05	0.13	0.18	0.06	0.06	0.05	0.00	0.02	0.01	0.03
11/28/2000	0.04	0.04	0.13	0.07	0.16	0.04	0.14	0.18	0.06	0.05	0.07	0.02	0.04	0.03	0.03
10/18/2001	0.05	0.05	0.12	0.07	0.15	0.03	0.11	0.15	0.06	0.04	0.07	0.01	0.04	0.02	0.04
10/15/2002	0.05	0.05	0.11	0.06	0.13	0.01	0.10	0.14	0.08	0.03	0.09	0.03	0.04	0.03	0.07
11/4/2003	0.04	0.06	0.12	0.06	0.13	0.01	0.10	0.16	0.06	0.05	0.09	0.01	0.03	0.03	NR
10/15/2004	0.06	0.06	0.11	0.06	0.15	0.01	0.12	0.18	0.08	0.05	0.08	0.02	0.04	0.01	NR
11/1/2005	0.05	0.05	0.14	0.07	0.17	0.04	0.13	0.18	0.07	0.06	0.09	0.01	0.04	0.02	NR
10/31/2006	0.06	0.05	0.15	0.08	0.18	0.05	0.14	0.20	0.06	0.05	0.07	0.01	0.03	0.01	NR
11/7/2007	0.06	0.06	0.15	0.09	0.24	0.05	0.12	0.20	0.06	0.06	0.08	0.01	0.03	0.02	NR
10/9/2008	0.07	0.07	0.15	0.10	0.19	0.06	0.15	0.19	0.08	0.07	0.07	0.02	0.02	0.00	NR
change in disp.	0.01	0.00	0.00	0.01	-0.05	0.01	0.03	-0.01	0.02	0.01	-0.01	0.02	0.00	-0.01	NR
11/07 to 10/08				Average change since last survey in ft =			0.00	or 0.0"							

Notes:

1) Negative vertical displacement represents settlement
2) Positive vertical displacement represents heave
3) NR = monument survey data not recorded
4) Displacement is net movement since 1988
5) Resultant vectors calculated by vector addition of Northings & Eastings



Reference information and notes:

1) This map is a compilation of aerial mapping, survey field data, and digitized construction maps. Maximum error could be ± one foot vertical and horizontal
2) Grid is based on California Coordinate System, Zone III, NAD 83.
3) Elevations based on N.G.S. Vertical datum, NAVD 88. The DE between NAVD 29 and NGVD 88 is 2.80′
4) Photogrammetric mapping: Transvision, Photo date 12/11/97; color photo date April 2001
5) file W:\geology\DAMS\Historic Dam Geology\anderson\ANDHistgeo.cdr
6) selected 1987-88 dam raise values in feet shown in red

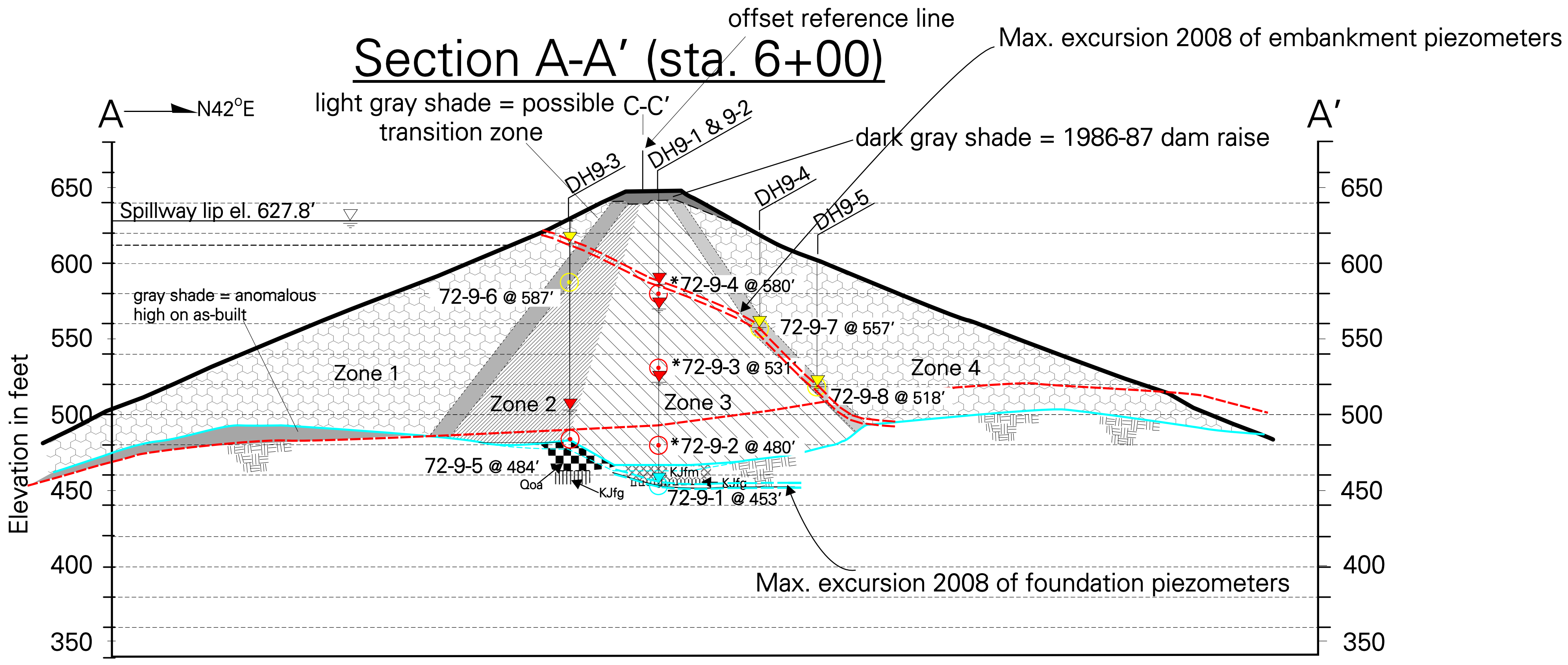
DATE
01/20/09
DESIGN
JLN
DRAWN
JLN
CHECKED
RLV

Santa Clara Valley Water District

Topographic Map
Leroy Anderson Dam
Surveillance Instrumentation

SCALE
1″ = 200′
FIGURE
1

Section A-A' (sta. 6+00)



Explanation

DH9-5 boring number

72-9-8 ⊙ vibrating wire piezometer

excavated topography (as-built) adjusted to DIP drill hole logs

excavated topography (as-built) adjusted 2.8' for new datum

original topography adjusted 2.8' for new datum

Bedrock & Soil Foundation Units from DIP

▦ Qoa = Quaternary older alluvium and/or colluvium

▨ KJfm = Franciscan Complex melange

▥ KJfg = Franciscan Complex greenstone

⊙ red = embankment	▼ embankment
⊙ yellow = transition zone	▼ transition zone
⊙ green = colluvium/alluvium	▼ colluvium/alluvium
⊙ blue = foundation	▼ foundation bedrock

* = installed using grout-in methods (see text)
all other piezometers installed using sand-pack methods

Notes:
1) File: W:\geology\dams\Historic_Dam_Geology\Anderson\andxsecA-A'rev.cdr
2) basis of elevations is NAVD 1988-elevations are 2.80' higher than NGVD 1929

DATE
12/18/08
DESIGN
RLV
DRAWN
JLN
CHECKED
RLV

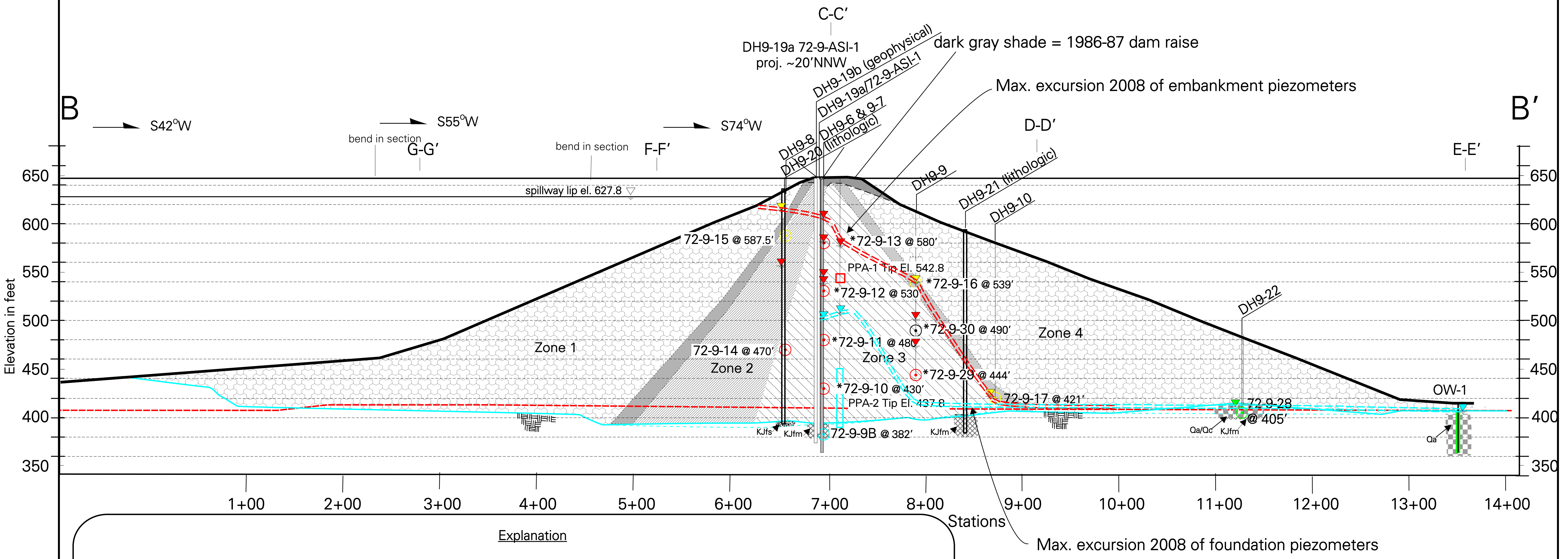
Santa Clara Valley Water District

Cross Section A-A'

Leroy Anderson Dam (No. 72-9)

SCALE
1"=100'
FIGURE
2

Section B-B′ (transverse max section along thalweg)



Explanation

boring number DH9-22

72-9-28 ⊙ vibrating wire piezometer

72-9-ASI-2 automated slope indicator

DH9-20 geophysical

DH9-20 lithologic logging

excavated topography (as-built) corrected 2.8′ for new datum

excavated topography (as-built) adjusted to DIP drill hole logs

original topography corrected 2.8′ for new datum

Bedrock and Foundation Soil Units from DIP

▦ Qa/Qc = Quaternary alluvium and/or colluvium

▨ KJfm = Franciscan Complex melange

⊙ red = embankment
⊙ yellow = transition zone
⊙ green = colluvium/alluvium
⊙ blue = foundation

▼ embankment
▼ transition zone
▼ colluvium/alluvium
▼ foundation bedrock

* = installed using grout-in methods (see text)
all other piezometers installed using sand-pack methods

Notes:
1) File: W:\geology\dams\historic dam geology\anderson\andxsecB-B′rev.cdr
2) basis of elevations is NAVD 1988-elevations are 2.80′ higher than NGVD 1929

DATE	12/18/08
DESIGN	RLV
DRAWN	JLN
CHECKED	RLV

Santa Clara Valley Water District

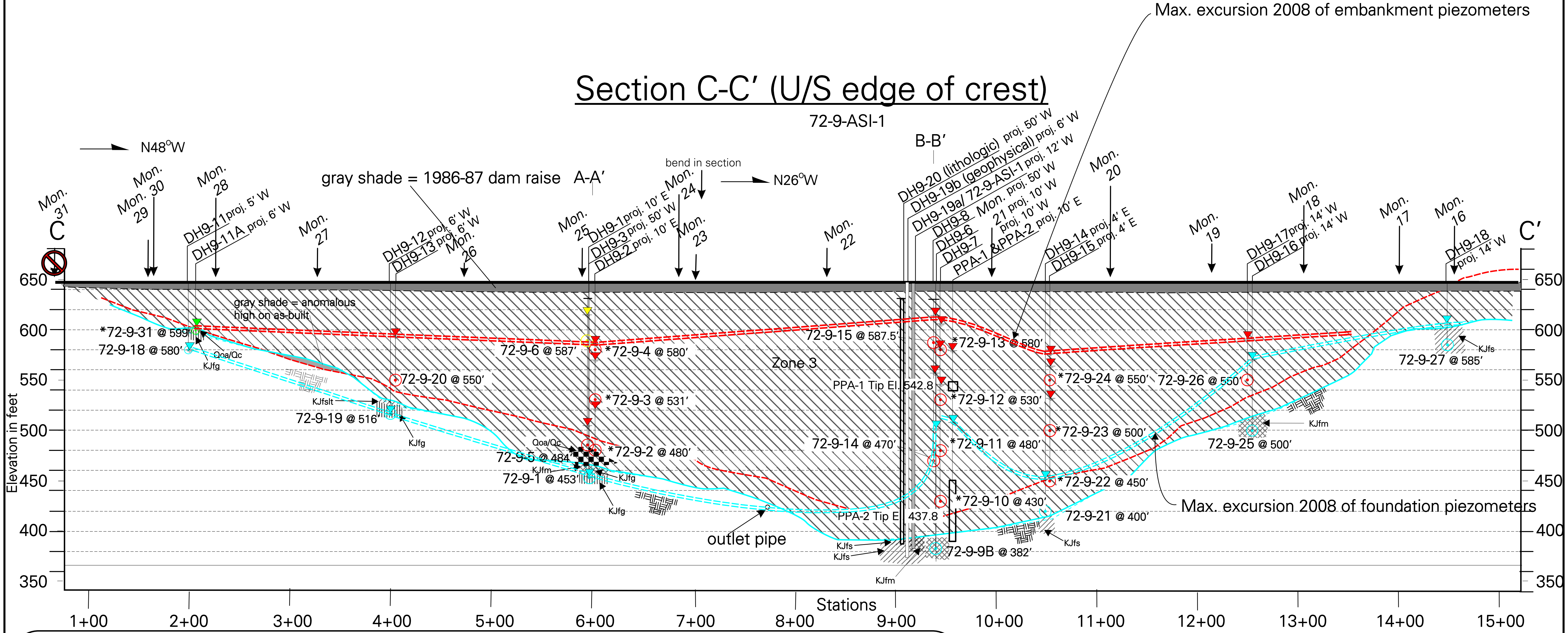
Cross Section B-B′

Leroy Anderson Dam (No. 72-9)

SCALE
1″=100′

FIGURE
3

Section C-C′ (U/S edge of crest)



Explanation

boring number DH9-18

vibrating wire piezometer 72-9-27 ⊙

72-9-ASI-2 automated slope indicator

DH9-20 geophysical/ lithologic logging

excavated topography (as-built) corrected 2.8′ for new datum

original topography corrected 2.8′ for new datum

excavated topography (as-built) adjusted to DIP drill hole logs

* = installed using grout-in methods (see text)
all other piezometers installed using sand-pack methods

Bedrock and Foundation Soil Units from DIP

▨ Qoa/Qc = Quaternary older alluvium and/or colluvium
▨ KJfm = Franciscan Complex melange
▨ KJfg = Franciscan Complex greenstone
▨ KJfs = Franciscan Complex sandstone

⊙ red = embankment
⊙ green = colluvium/alluvium
⊙ blue = foundation

▼ embankment
▼ colluvium/alluvium
▼ foundation bedrock

Notes:
1) File: W:\Geology\DAMS\Historic_Dam_Geology\Anderson\andxsecC-CDIP.cdr
2) basis of elevations is NAVD 1988-elevations are 2.80′ higher than NGVD 1929

DATE	12/18/08
DESIGN	RLV
DRAWN	JLN
CHECKED	RLV

Santa Clara Valley Water District

Cross Section C-C′

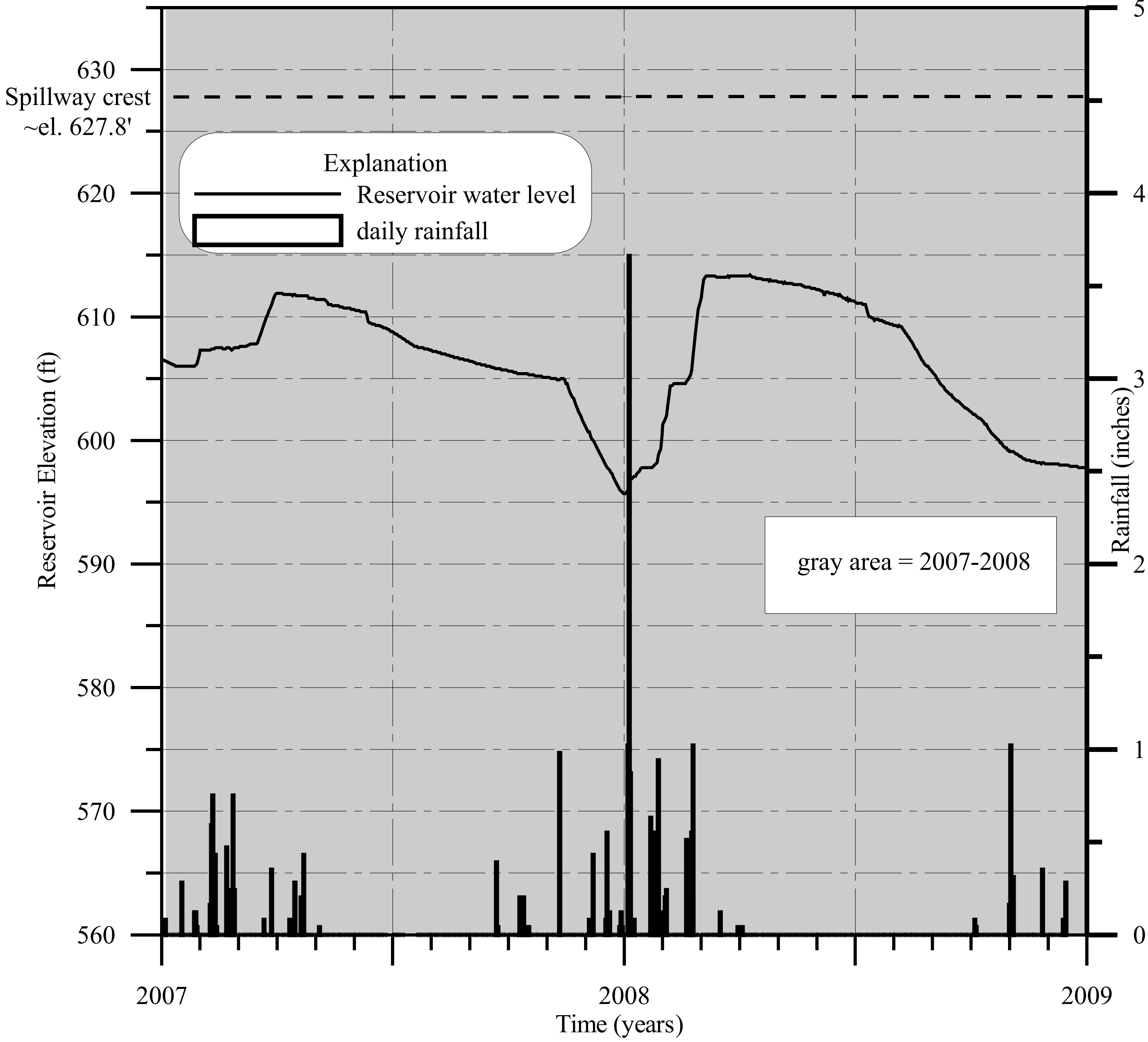
Leroy Anderson Dam (No. 72-9)

SCALE
1″=100′

FIGURE
4

LEROY ANDERSON DAM (No. 72-9)

Santa Clara Valley Water District



Notes: 1) basis of elevations is NAVD 1988 - values are 2.8 feet higher than NGVD 1929
2) file W:\geology\dams\annual dam safety reports\DSOD\2008\piez&weirdata\Andresplot-08

Figure 5. Daily Reservoir Elevation and Rainfall 2007-2008

LEROY ANDERSON DAM (No. 72-9)

Santa Clara Valley Water District

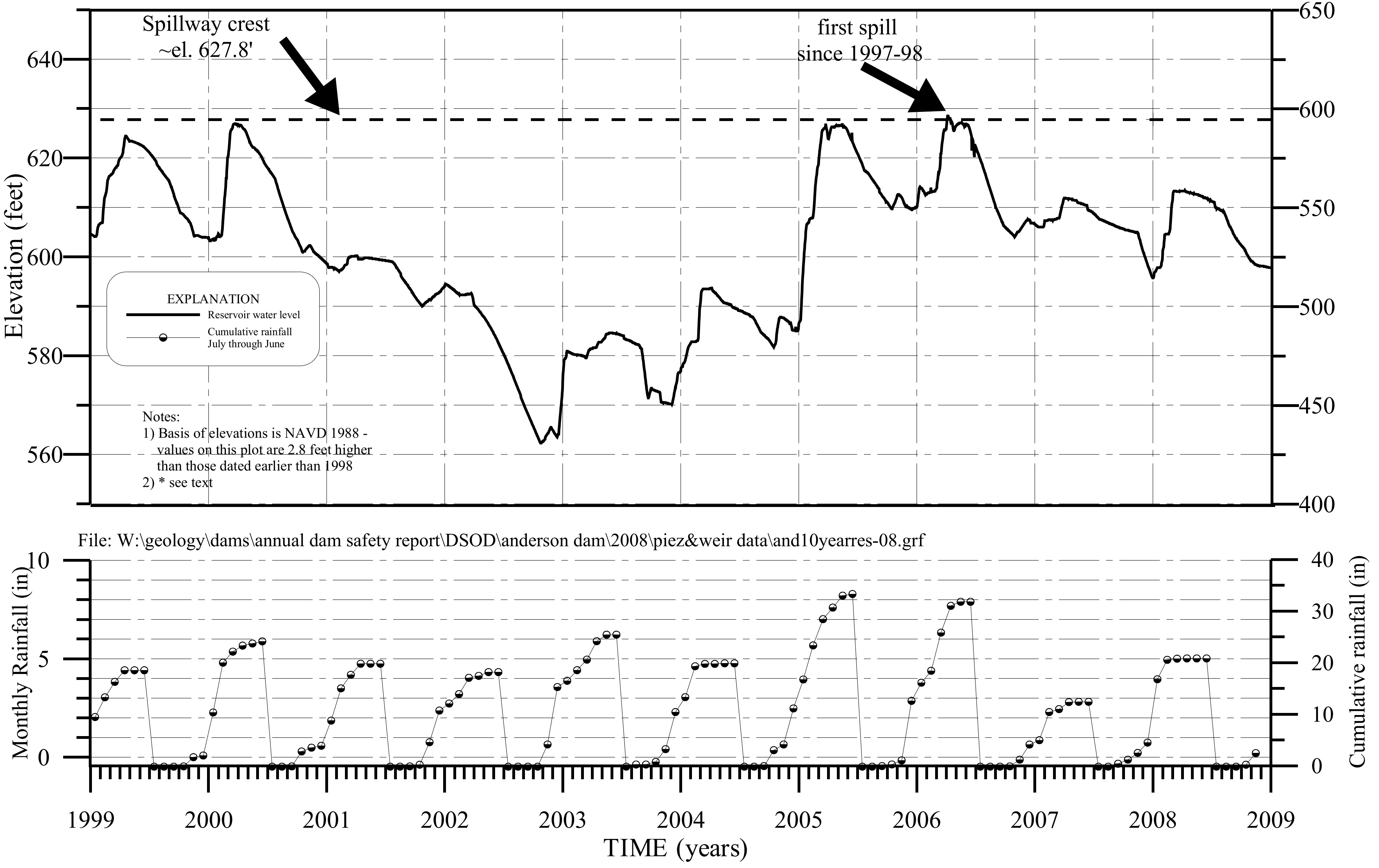


Figure 6. 10 Year Reservoir Levels

LEROY ANDERSON DAM (No. 72-9)

Santa Clara Valley Water District

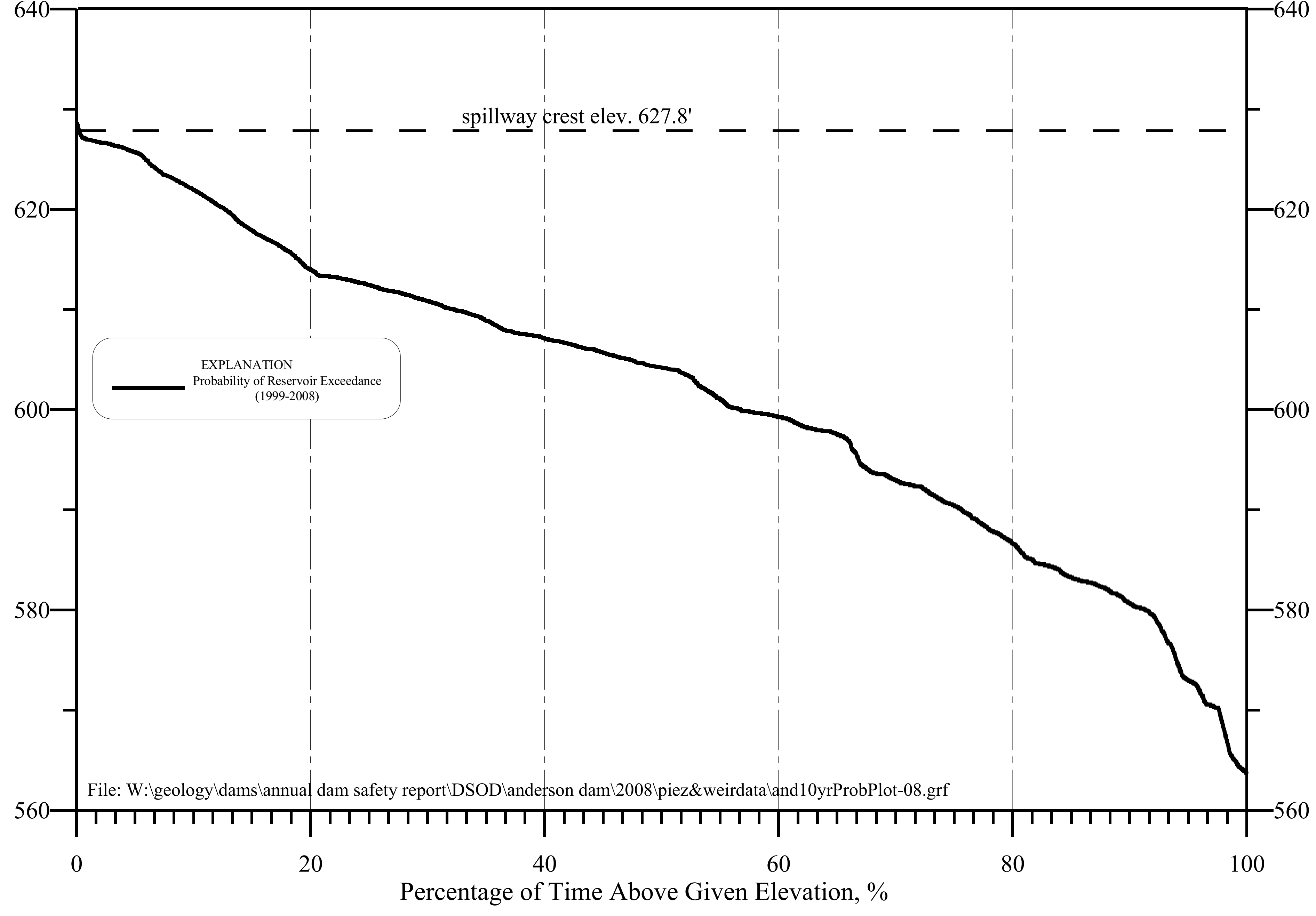


Figure 7. Probability of Reservoir Exceedance (1999-2008)

LEROY ANDERSON DAM (No. 72-9)

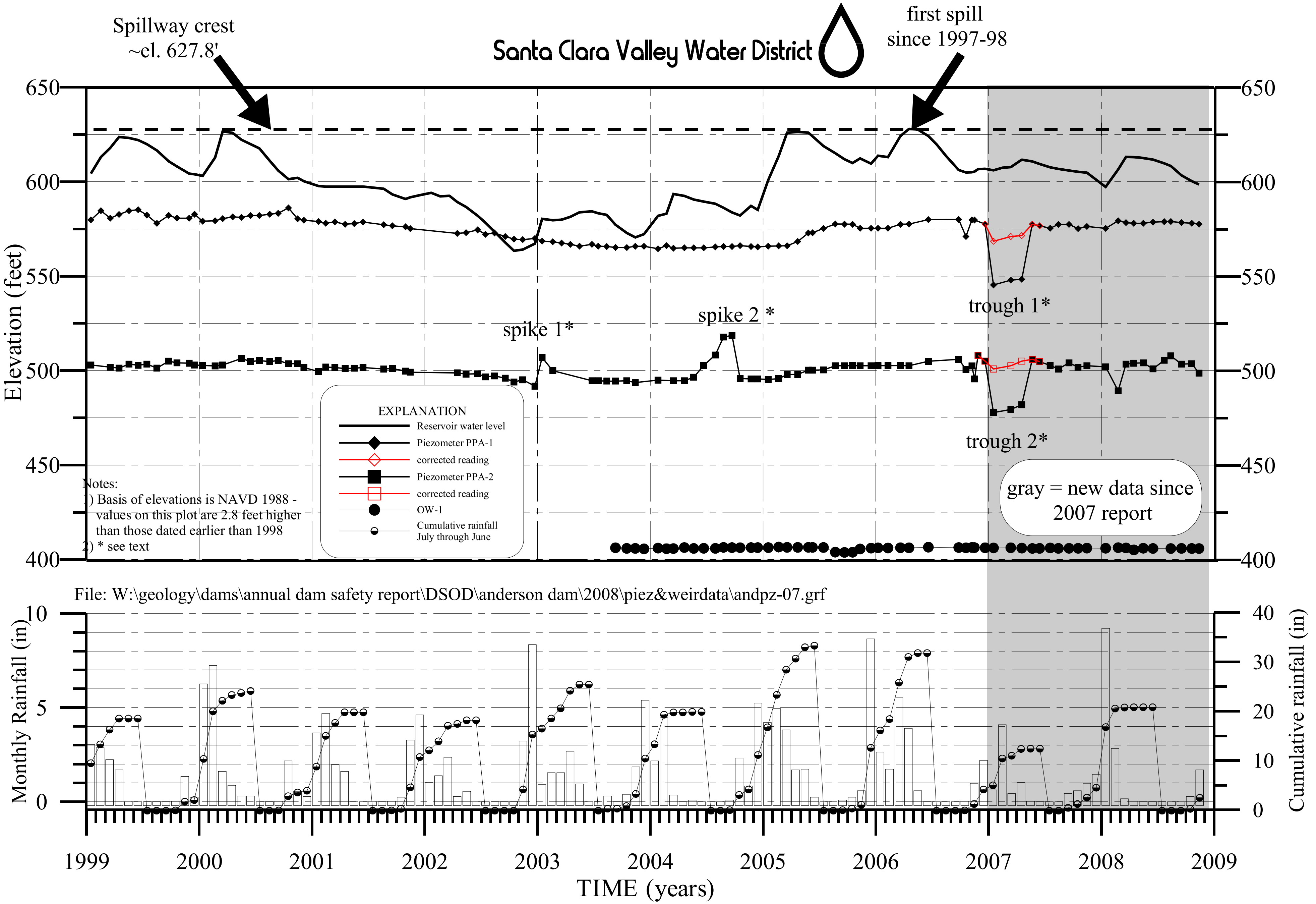
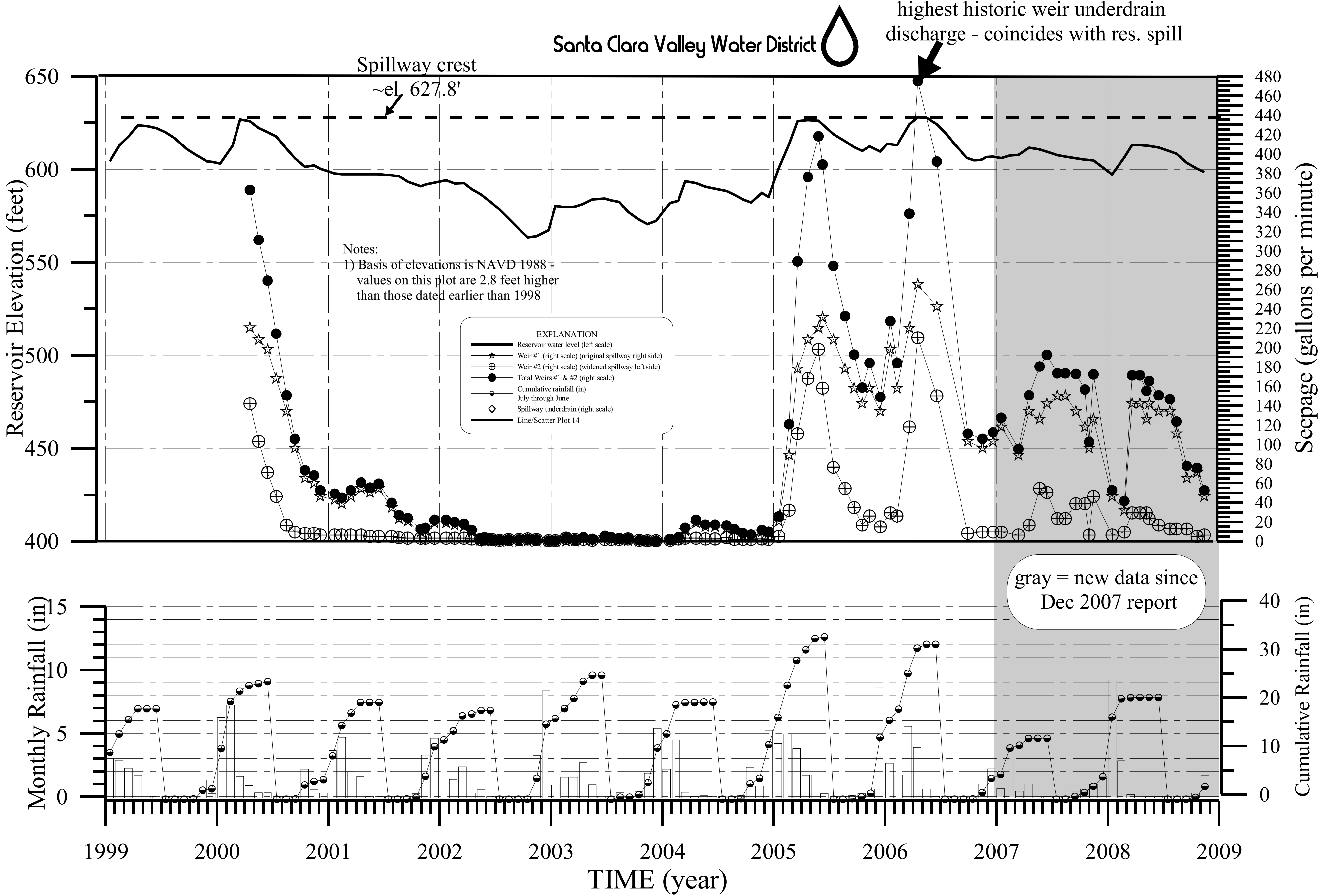


Figure 8. Piezometer Levels - Embankment

LEROY ANDERSON DAM (No. 72-9)



File: W:\geology\dams\annual dam safety report\DSOD\Anderson Dam\2008\piez&weirdata\andweir-08.grf

Figure 9. Weir Discharge Data - Spillway Underdrains

LEROY ANDERSON DAM (No. 72-9)

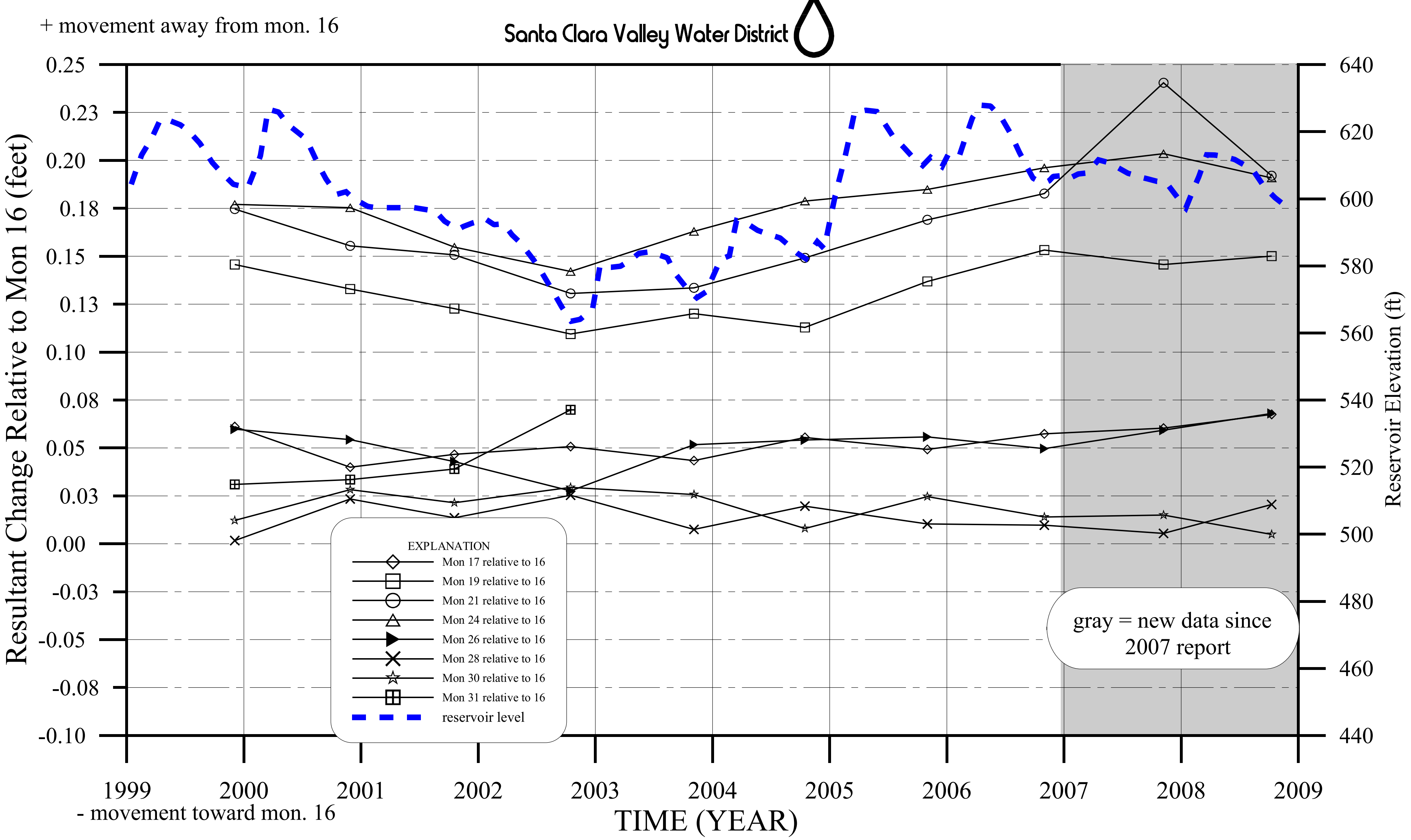


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Figure 10 - Resultant Displacement (RDD) Relative to Mon 16 - Monuments at Downstream Edge of Crest

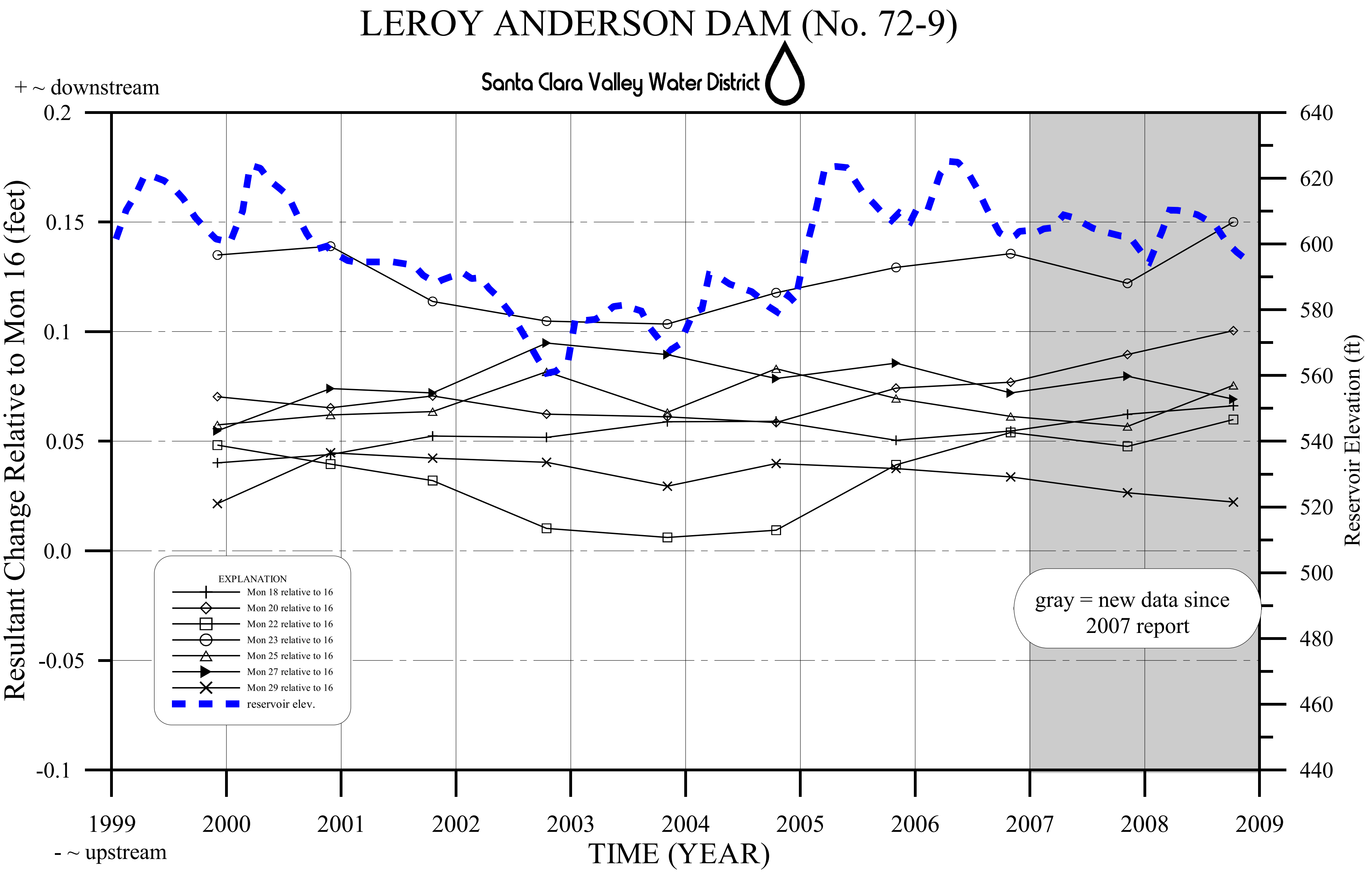

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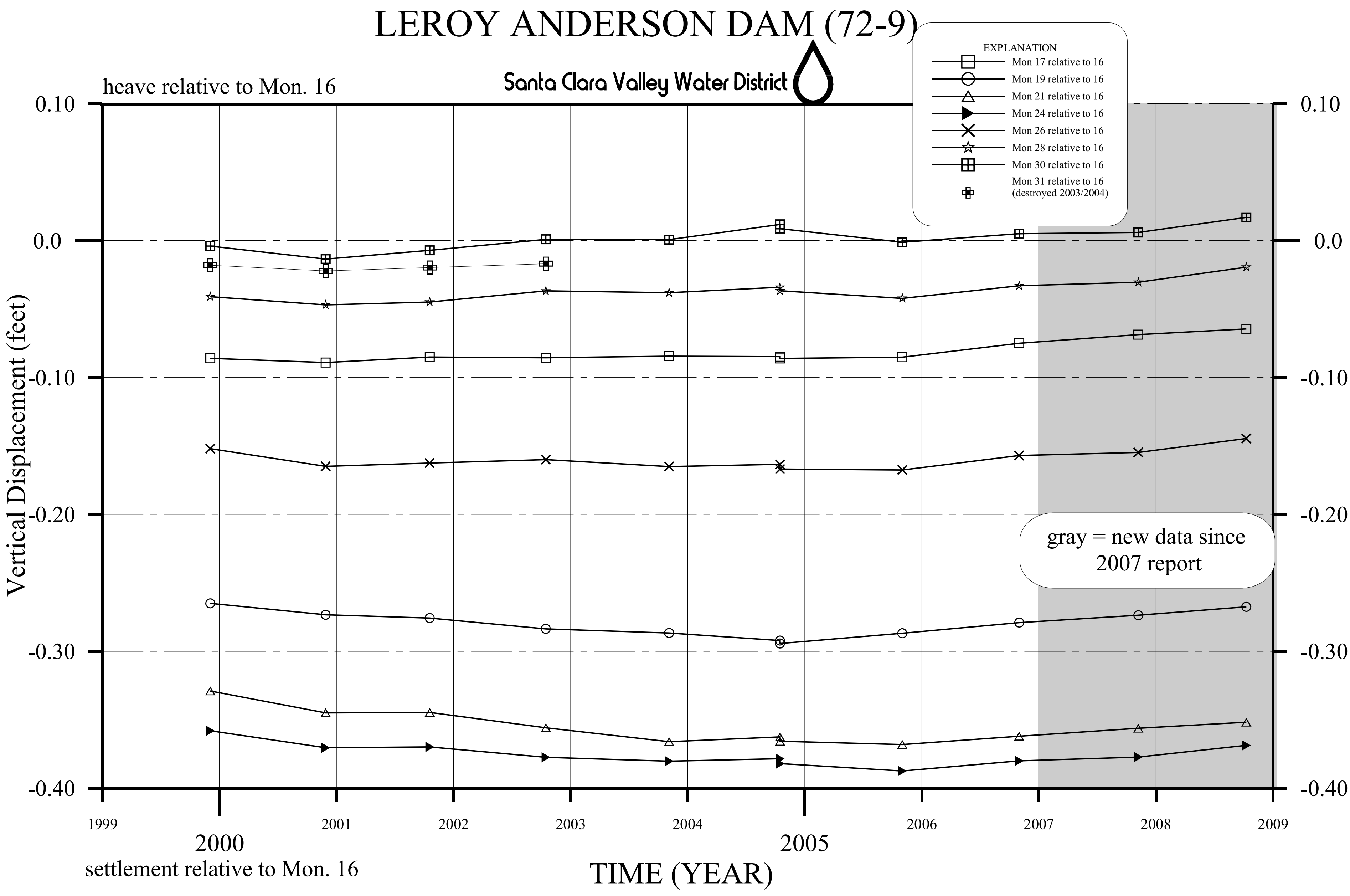
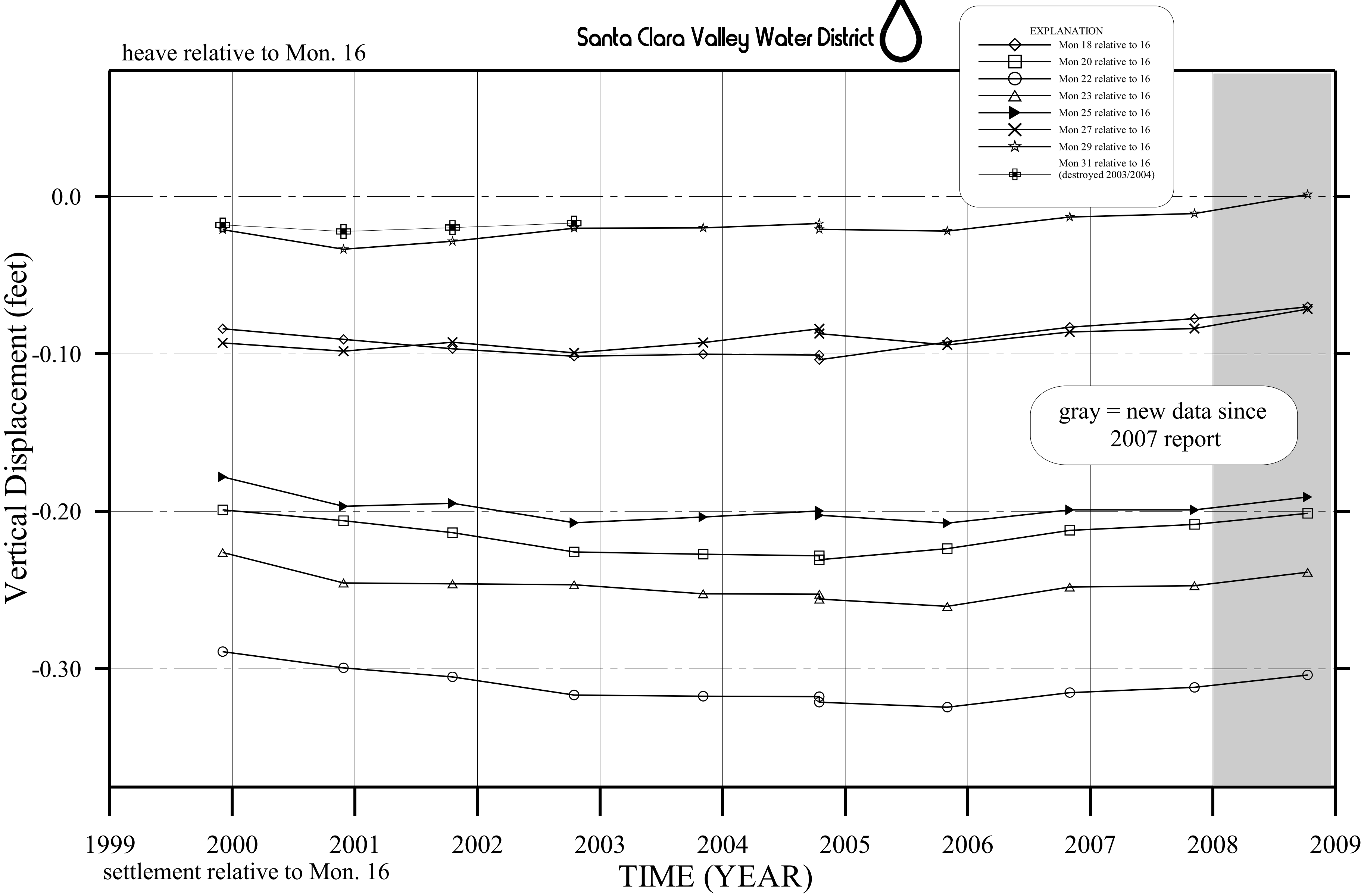
Figure 11 - Resultant Displacement (RDD) Relative to Mon 16 - Monuments at Upstream Edge of Crest



File W:\geology\annual dam safety reports\DSOD\anderson dam\2008\survey\andvert1-08.grf

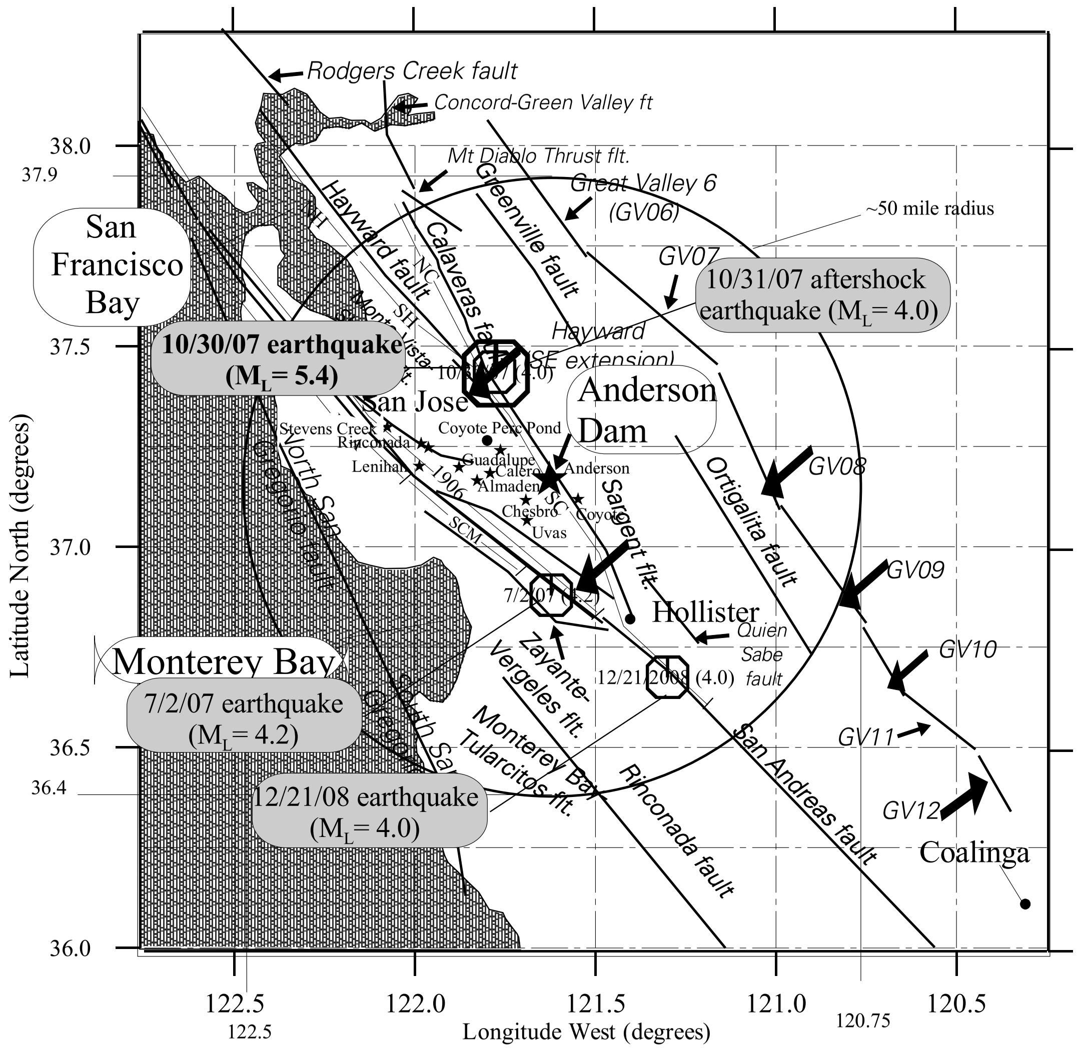
Figure 12 - Vertical Displacement (DD) Relative to Mon. 16 - Monuments at Downstream Edge of Crest

LEROY ANDERSON DAM



File W:\geology\annual dam safety reports\FERC\annual reports\2008\surveydata\andvert1-08.grf

Figure 13 - Vertical Displacement (DD) Relative to Mon. 16 - Monuments at Upstream Edge of Crest



Explanation

Significant earthquakes (see text)

Noteworthy earthquakes (see text)

★ District Dams

10/30/07 Alum Rock 5.6 earthquake

	site	site distance to earthquake in miles	Estimated acceleration g
1	Coyote Perc Dam	13.3	0.12
2	Rinconada Reservoir	16.7	0.05
3	Vasona Perc. Dam	16.4	0.05
4	Guadalupe Dam	17.0	0.05
5	Calero Dam	17.2	0.04
6	Almaden Dam	18.7	0.04
7	Stevens Creek Dam	18.9	0.04
8	James J.Lenihan Dam	19.8	0.04
9	Leroy Anderson Dam	20.0	0.04
10	Elmer J. Chesbro Dam	22.3	0.03
11	Coyote Dam	25.0	0.03
12	Uvas Dam	25.8	0.02

N

0 20

Scale in Miles

Site Coordinates: Latitude: 37.165 N
Longitude: 121.629 W

Notes: 1) File W:\geology\dams\annual dam safety reports\DSOD\anderson dam\2008\seismicity\Andersonseis-08.grf

DATE	1/05/09
DESIGN	JLN
DRAWN	JLN
CHECKED	DEH

Santa Clara Valley Water District

Regional Fault Map, Showing M 5.4 Eq.
on 10-30-07 and Noteworthy Earthquakes

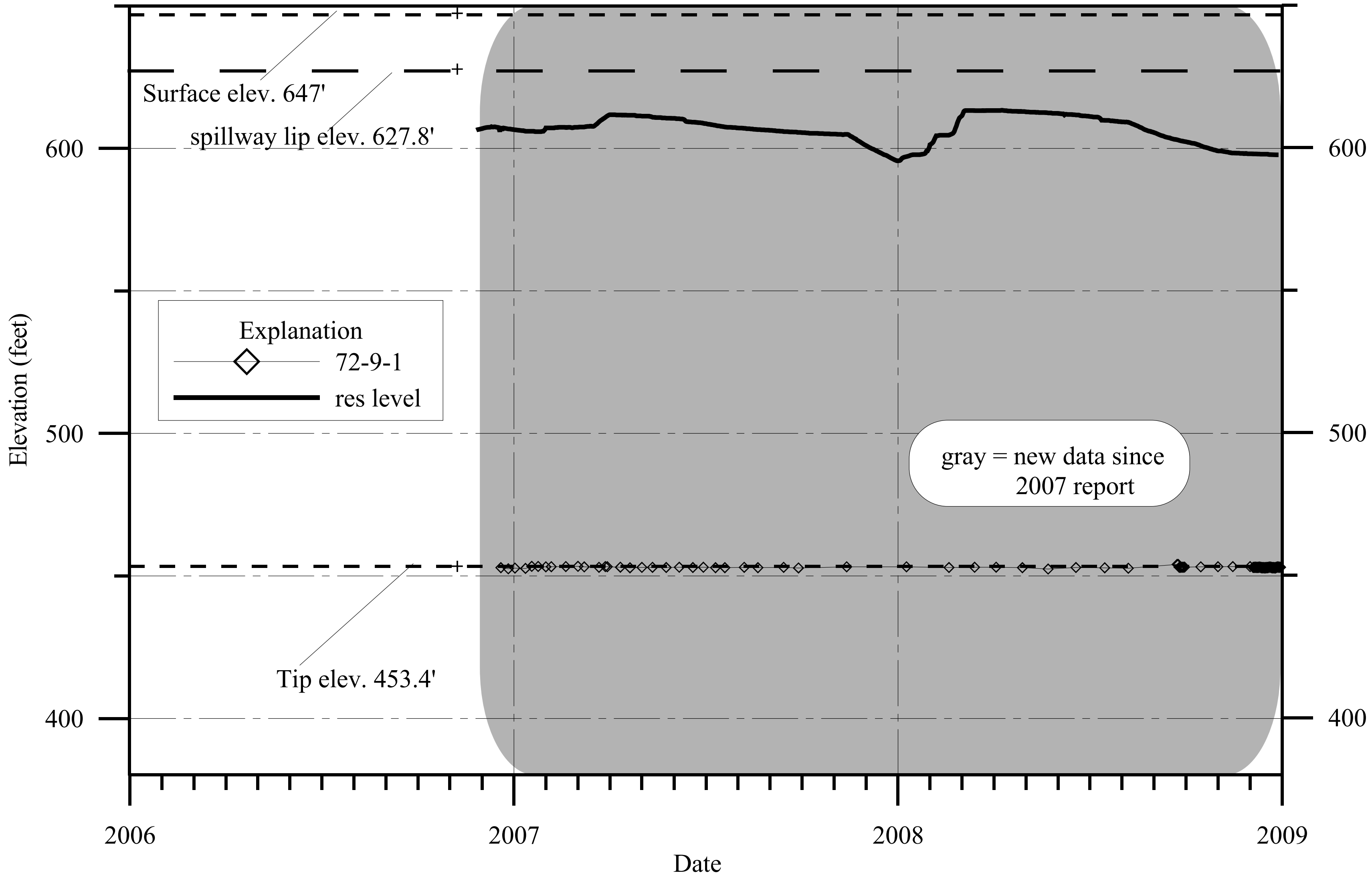
Anderson Dam (No. 72-9)

SCALE
1"=20'

FIGURE
14

Appendix A – New Plots of Vibrating Wire Piezometer and Reservoir Elevation

Figures A-1 through A-31 Plots of Vibrating Wire Piezometers and Reservoir Elevations versus Time at Leroy Anderson Dam



Left Central Foundation

Notes: 1) Basis of elevations is NAVD 1988. Reservoir level data were corrected from 1929 to 1988 datum by adding 2.80 feet
2) Some data not plotted due to erroneously low values-see tables
3) W:\Geology\DAMS\Annual Dam Safety Reports\DSOD\anderson dam\2008\72-9-01_08.grf

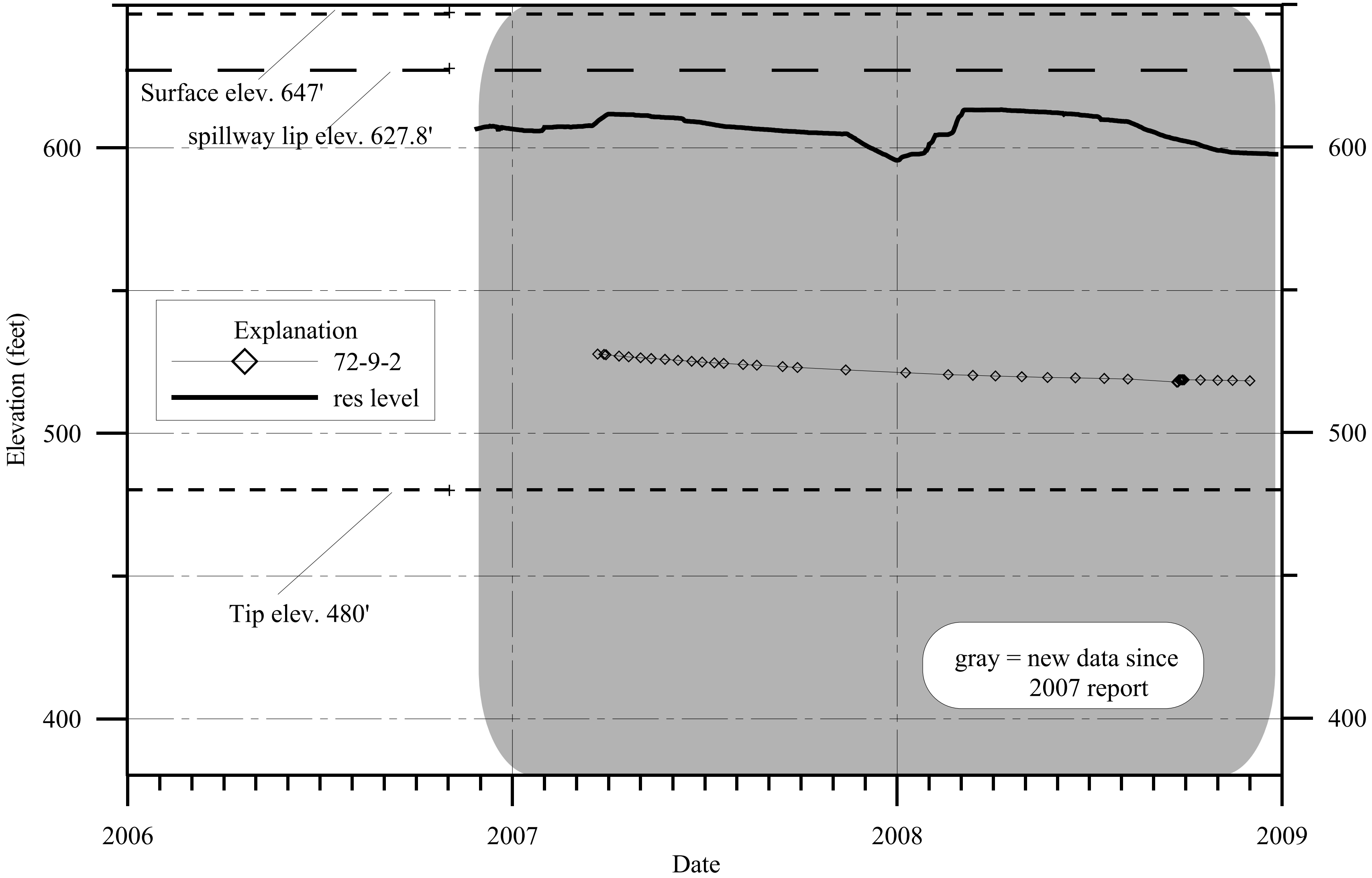
DATE 12/30/08
DESIGN JLN
DRAWN JLN
CHECKED RLV

Santa Clara Valley Water District

72-9-1

Anderson Dam No. 72-9

SCALE as-shown
FIGURE A-1



Lower (Left) Zone 3 (Core)

Notes: 1) Basis of elevations is NAVD 1988. Reservoir level data were corrected from 1929 to 1988 datum by adding 2.80 feet
2) Some data not plotted due to erroneously low values-see tables
3) W:\Geology\DAMS\Annual Dam Safety Reports\DSOD\anderson dam\72-9-02_08.grf

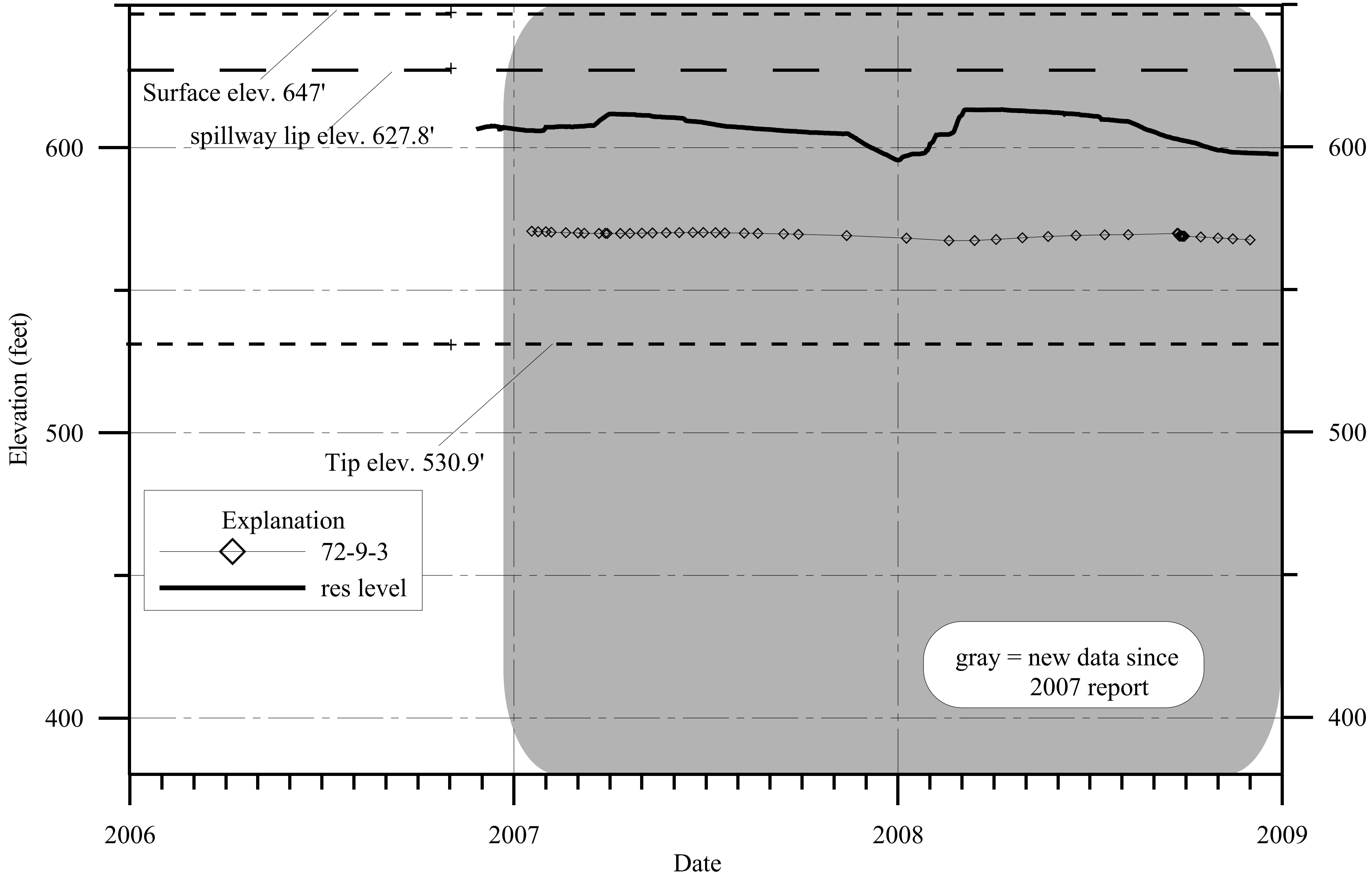
DATE 12/30/08
DESIGN JLN
DRAWN JLN
CHECKED RLV

Santa Clara Valley Water District

72-9-2

Anderson Dam No. 72-9

SCALE as-shown
FIGURE A-2



Mid-Elevation Zone 3 (Core)

Notes: 1) Basis of elevations is NAVD 1988. Reservoir level data were corrected from 1929 to 1988 datum by adding 2.80 feet
2) Some data not plotted due to erroneously low values-see tables
3) W:\Geology\DAMS\Annual Dam Safety Reports\DSOD\anderson dam\72-9-03_08.grf

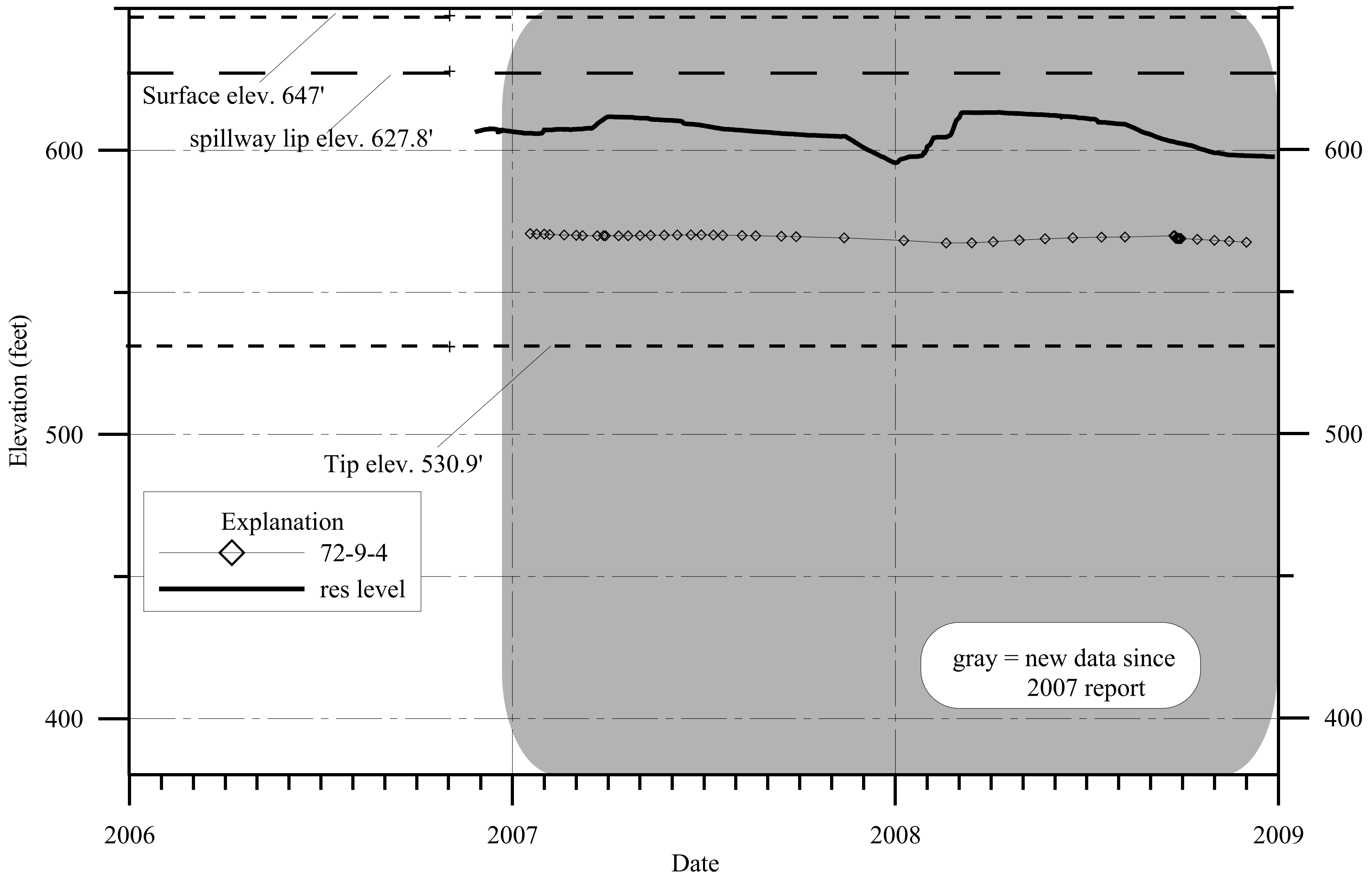
DATE 12/30/08
DESIGN JLN
DRAWN JLN
CHECKED RLV

Santa Clara Valley Water District

72-9-3

Anderson Dam No. 72-9

SCALE as-shown
FIGURE A-3



Upper-Elevation Zone 3 (Core)

Notes: 1) Basis of elevations is NAVD 1988. Reservoir level data were corrected from 1929 to 1988 datum by adding 2.80 feet
2) Some data not plotted due to erroneously low values-see tables
3) W:\Geology\DAMS\Annual Dam Safety Reports\DSOD\anderson dam\2008\72-9-04_08.grf

DATE	12/30/08
DESIGN	JLN
DRAWN	JLN
CHECKED	RLV

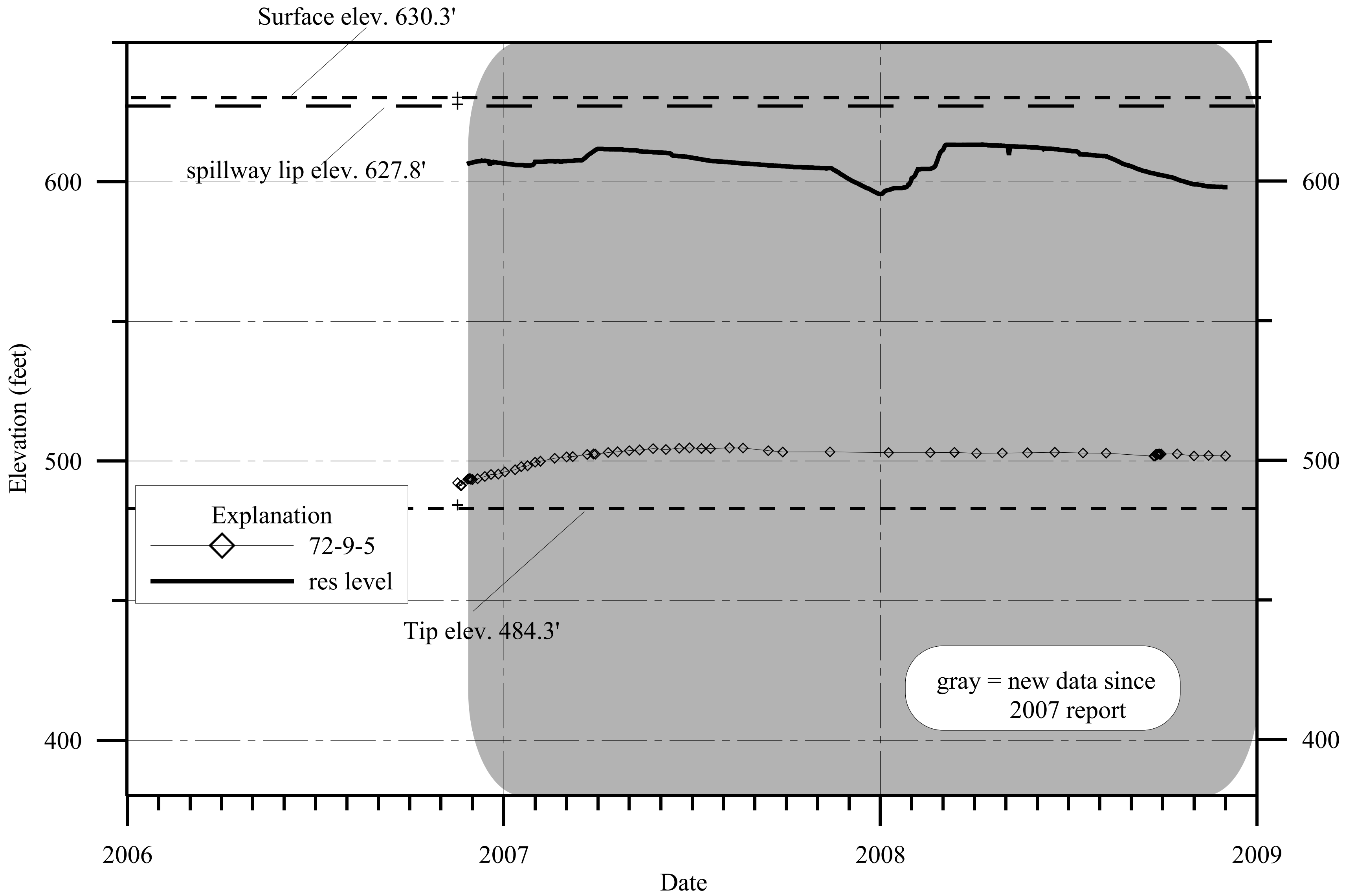
Santa Clara Valley Water District

72-9-4

Anderson Dam No. 72-9

SCALE
as-shown

FIGURE
A-4



Zone 2/3 (Core) and Upstream Foundation

Notes: 1) Basis of elevations is NAVD 1988. Reservoir level data were corrected from 1929 to 1988 datum by adding 2.80 feet
2) Some data not plotted due to erroneously low values-see tables
3) W:\Geology\DAMS\Annual Dam Safety Reports\DSOD\anderson dam \2008\72-9-05_08.grf

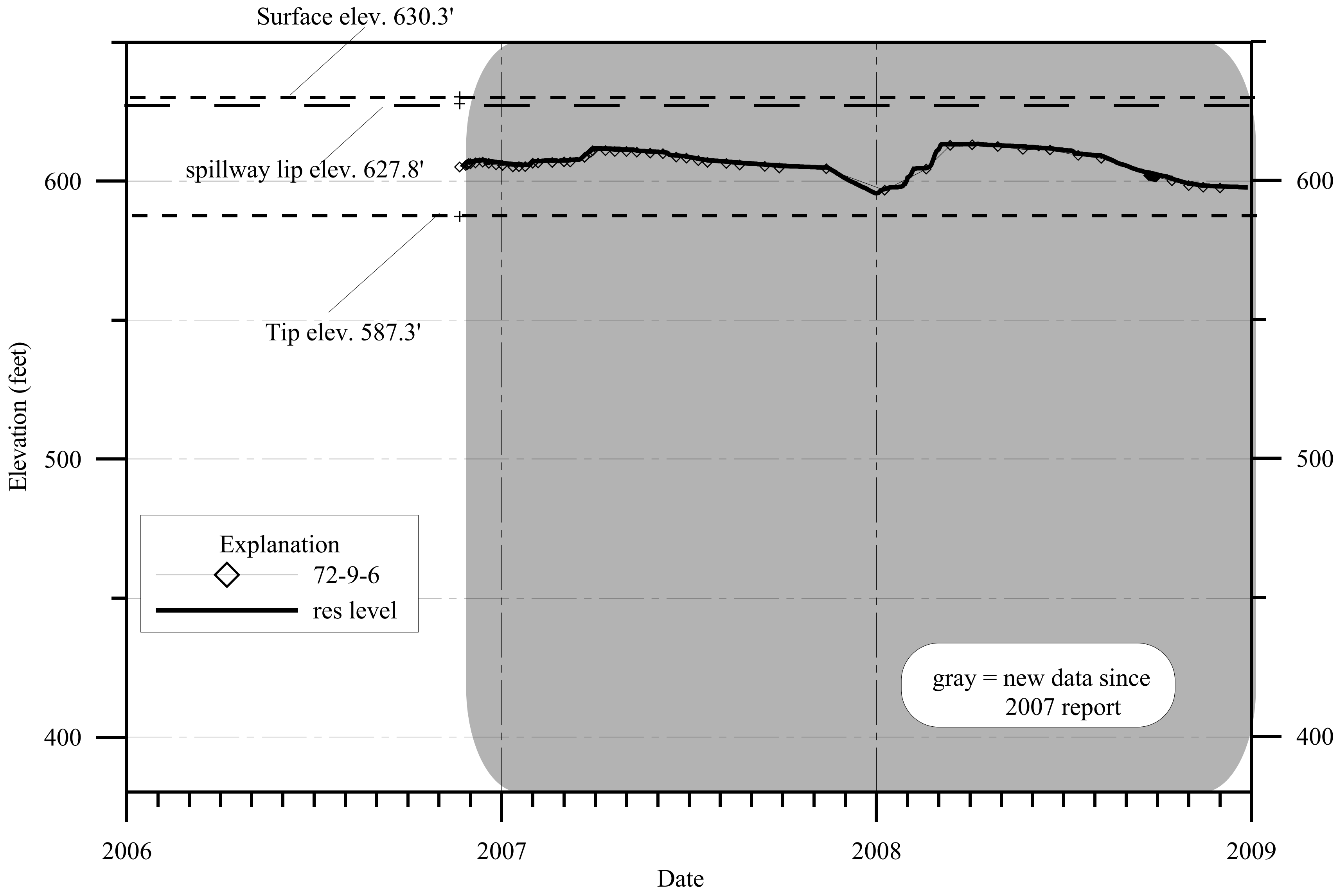
DATE 12/30/08
DESIGN JLN
DRAWN JLN
CHECKED RLV

Santa Clara Valley Water District

72-9-5

Anderson Dam No. 72-9

SCALE as-shown
FIGURE A-5



Upstream Transition/Zone 2 Contact

Notes: 1) Basis of elevations is NAVD 1988. Reservoir level data were corrected from 1929 to 1988 datum by adding 2.80 feet
2) Some data not plotted due to erroneously low values-see tables
3) W:\Geology\DAMS\Annual Dam Safety Reports\DSOD\anderson dam \2008\72-9-06_08.grf

DATE	12/30/08
DESIGN	JLN
DRAWN	JLN
CHECKED	RLV

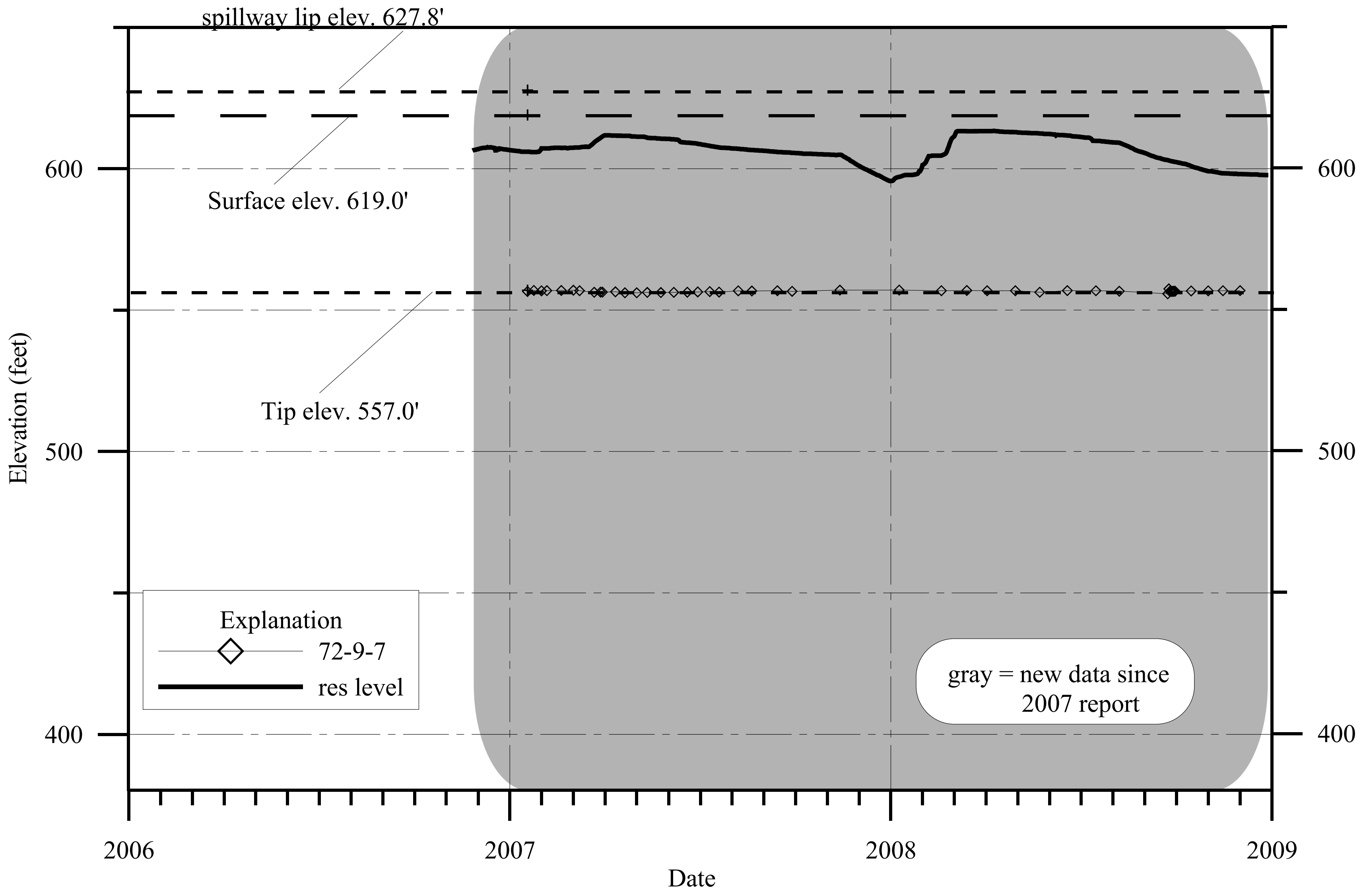
Santa Clara Valley Water District

72-9-6

Anderson Dam No. 72-9

SCALE
as-shown

FIGURE
A-6



Downstream Transition Zone

Notes: 1) Basis of elevations is NAVD 1988. Reservoir level data were corrected from 1929 to 1988 datum by adding 2.80 feet
2) Some data not plotted due to erroneously low values-see tables
3) W:\Geology\DAMS\Annual Dam Safety Reports\DSOD\anderson dam \2008\72-9-08_07.grf

DATE 12/30/08
DESIGN JLN
DRAWN JLN
CHECKED RLV

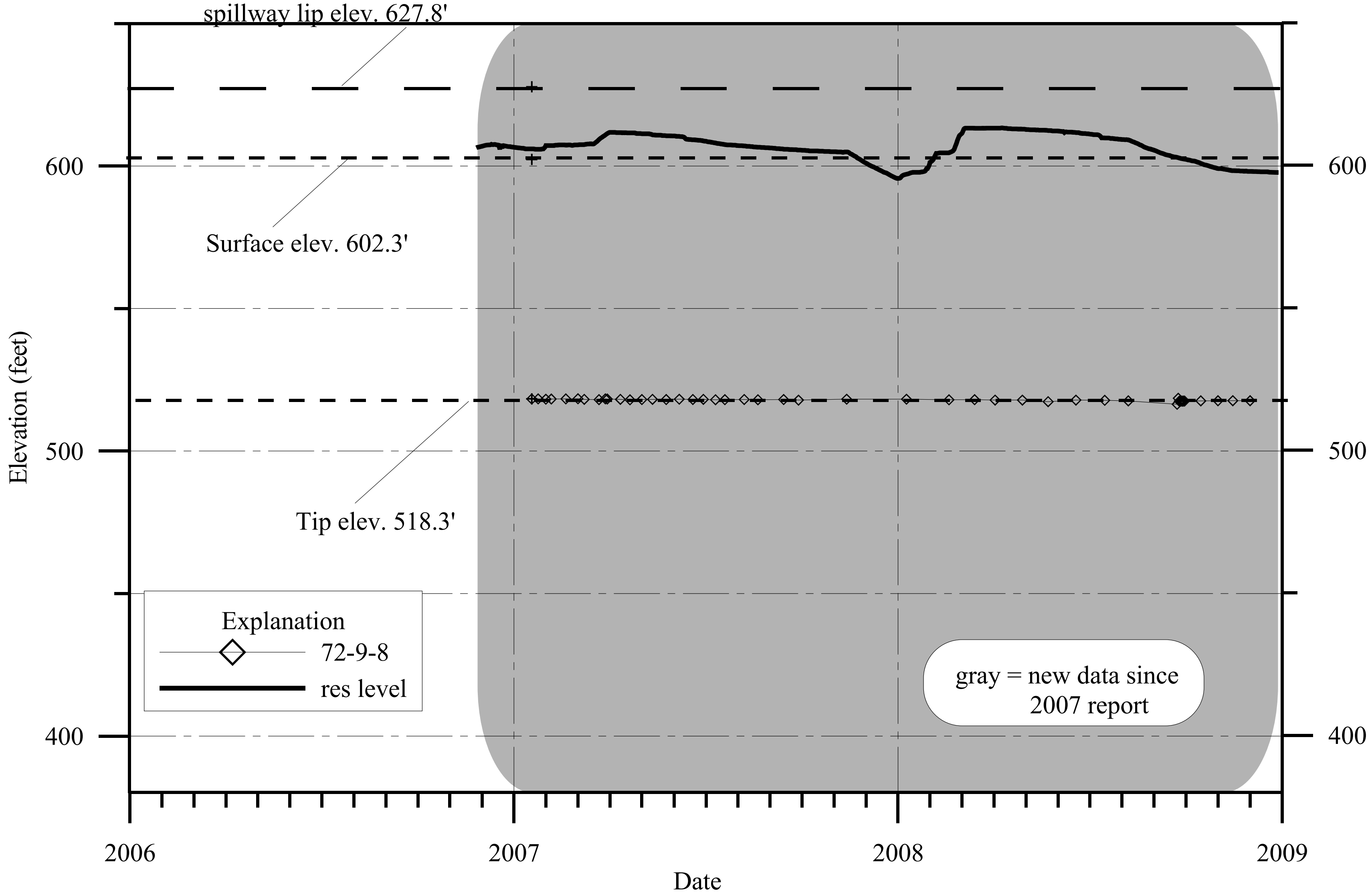
Santa Clara Valley Water District

72-9-7

Anderson Dam No. 72-9

SCALE as-shown

FIGURE A-7



Downstream Transition Zone

Notes: 1) Basis of elevations is NAVD 1988. Reservoir level data were corrected from 1929 to 1988 datum by adding 2.80 feet
2) Some data not plotted due to erroneously low values-see tables
3) W:\Geology\DAMS\Annual Dam Safety Reports\DSOD\anderson dam \2008\72-9-08_08.grf

DATE 12/30/08
DESIGN JLN
DRAWN JLN
CHECKED RLV

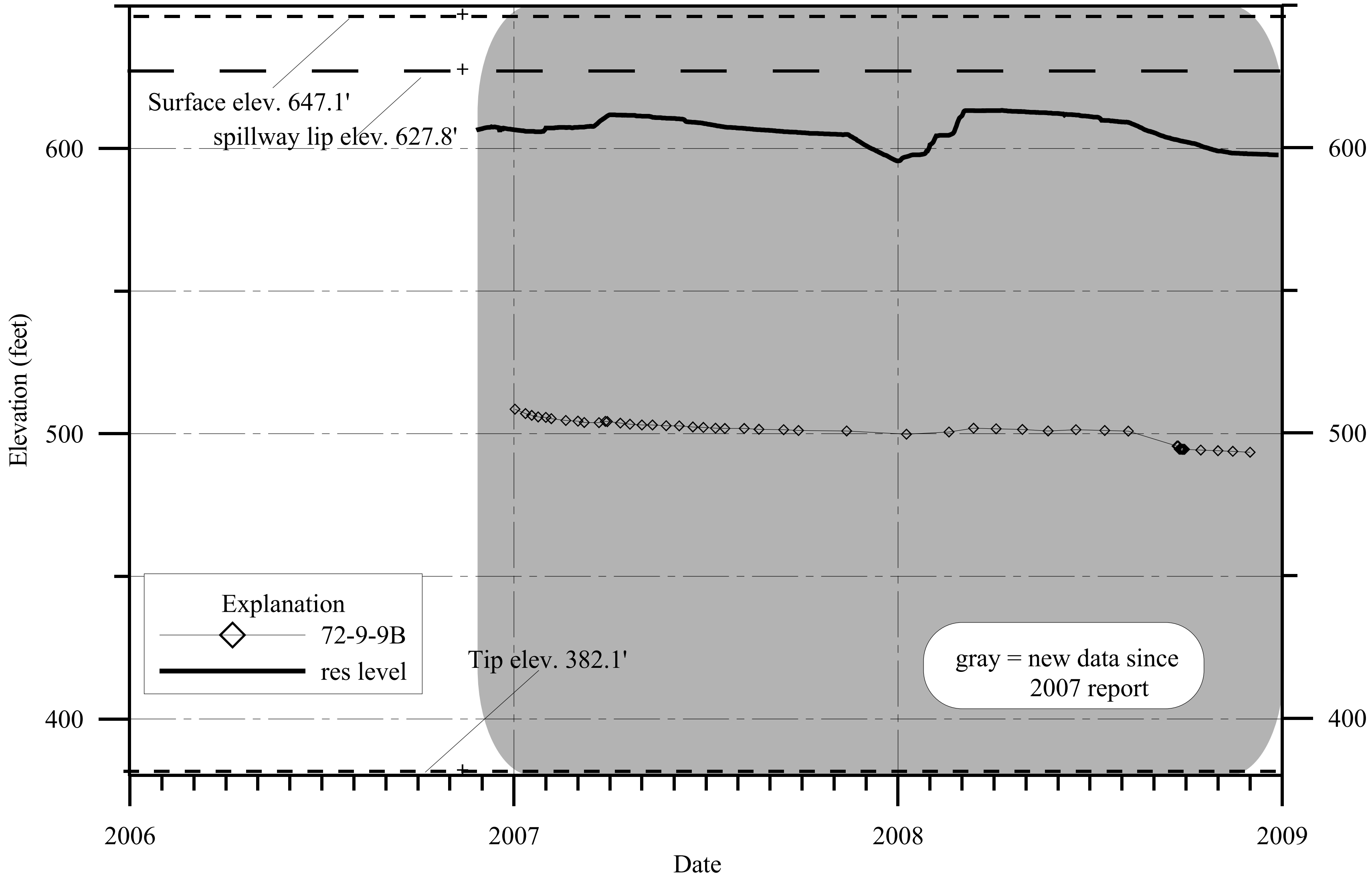
Santa Clara Valley Water District

72-9-8

Anderson Dam No. 72-9

SCALE as-shown

FIGURE A-8



Zone 3 (Core) Foundation

Notes: 1) Basis of elevations is NAVD 1988. Reservoir level data were corrected from 1929 to 1988 datum by adding 2.80 feet
2) Some data not plotted due to erroneously low values-see tables
3) W:\Geology\DAMS\Annual Dam Safety Reports\DSOD\anderson dam\2008\72-9-09B_08.grf

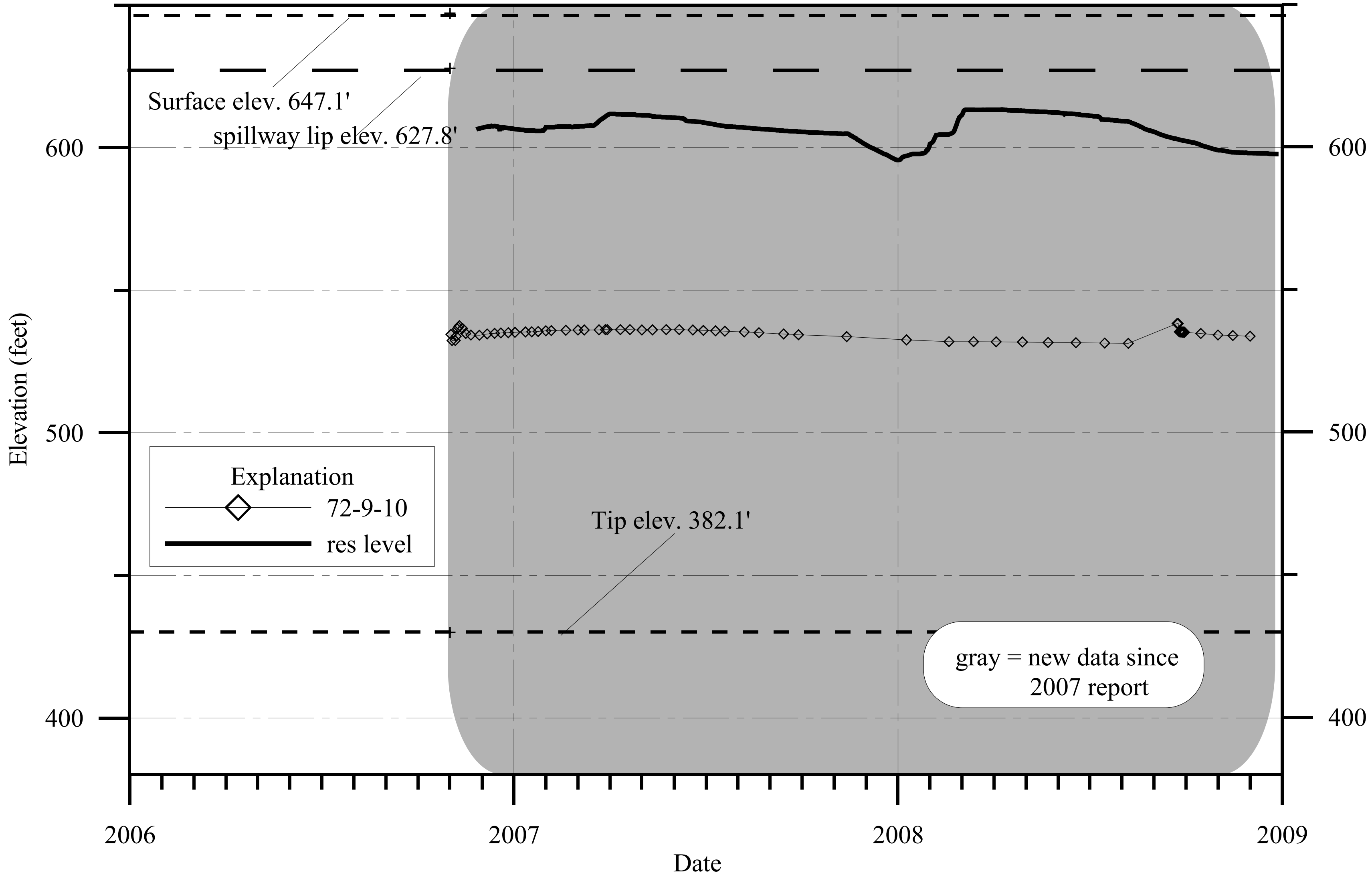
DATE 12/30/08
DESIGN JLN
DRAWN JLN
CHECKED RLV

Santa Clara Valley Water District

72-9-9B

Anderson Dam No. 72-9

SCALE as-shown
FIGURE A-9



Lower Elevation Zone 3

Notes: 1) Basis of elevations is NAVD 1988. Reservoir level data were corrected from 1929 to 1988 datum by adding 2.80 feet
2) Some data not plotted due to erroneously low values-see tables
3) W:\Geology\DAMS\Annual Dam Safety Reports\DSOD\anderson dam \2008\72-9-10_08.grf

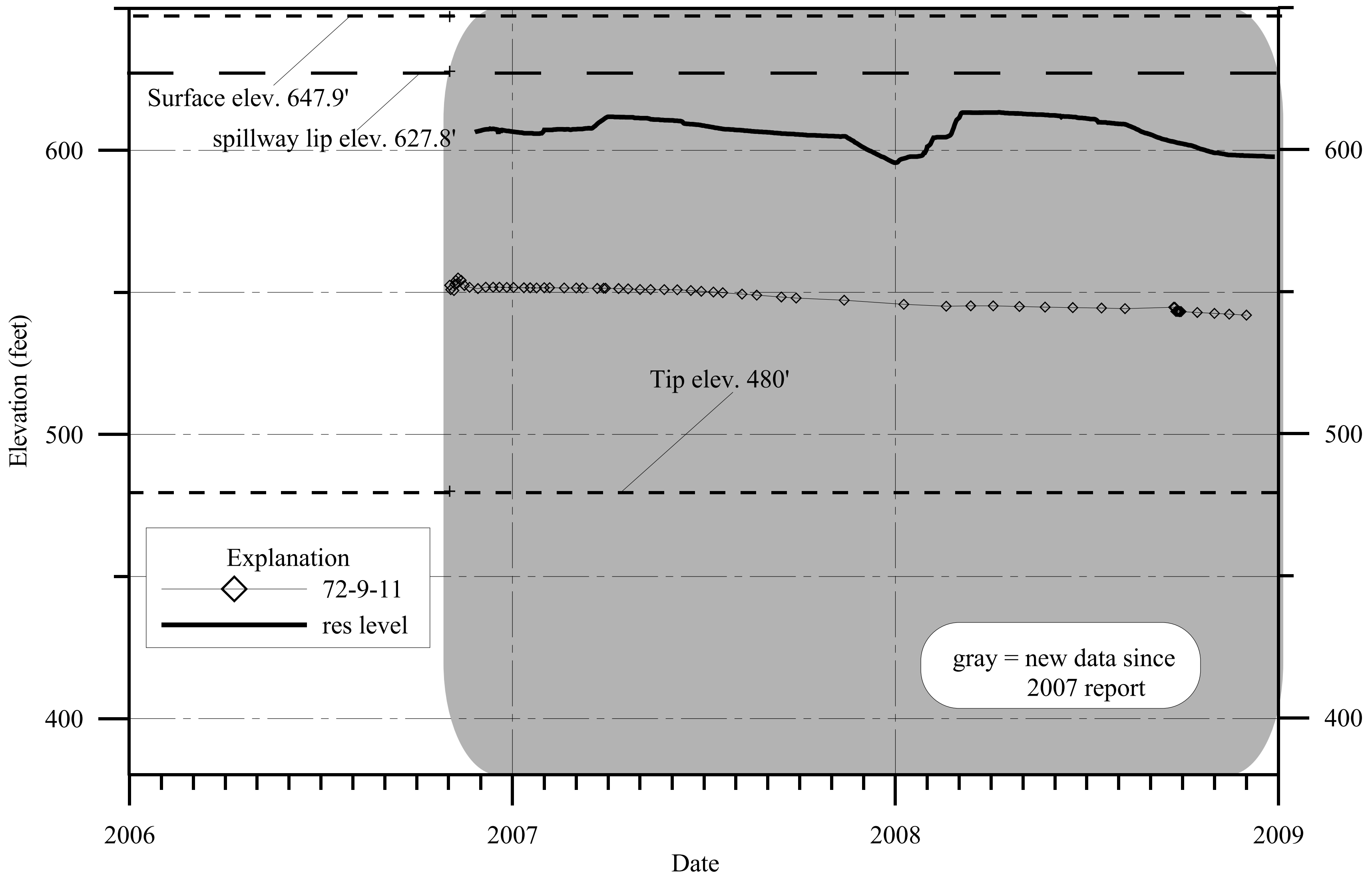
DATE 12/30/08
DESIGN JLN
DRAWN JLN
CHECKED RLV

Santa Clara Valley Water District

72-9-10

Anderson Dam No. 72-9

SCALE as-shown
FIGURE A-10



Lower Elevation Zone 3

Notes: 1) Basis of elevations is NAVD 1988. Reservoir level data were corrected from 1929 to 1988 datum by adding 2.80 feet
2) Some data not plotted due to erroneously low values-see tables
3) W:\Geology\DAMS\Annual Dam Safety Reports\DSOD\anderson dam \2008\72-9-11_08.grf

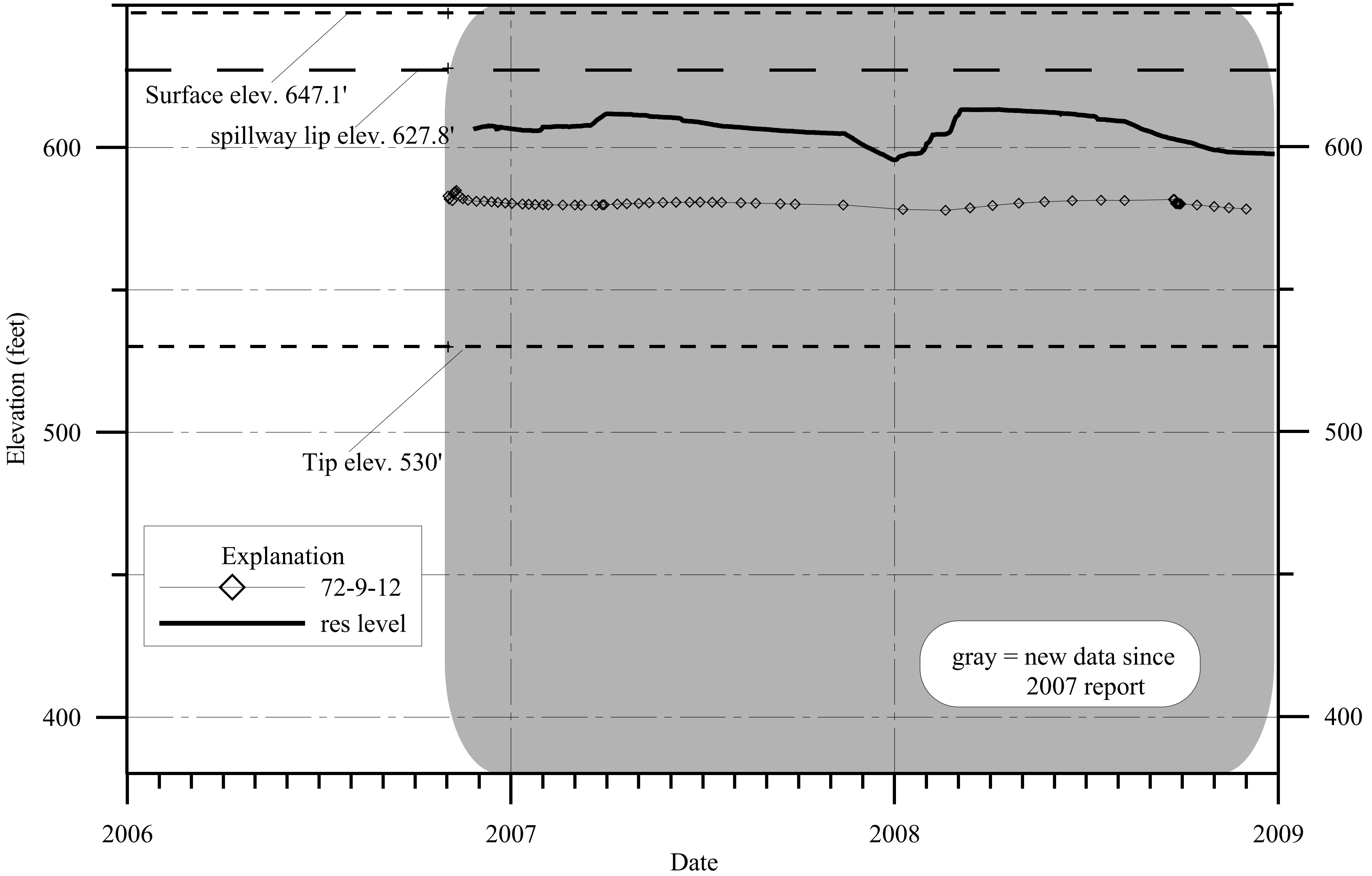
DATE	12/30/08
DESIGN	JLN
DRAWN	JLN
CHECKED	RLV

Santa Clara Valley Water District

72-9-11

Anderson Dam No. 72-9

SCALE
as-shown
FIGURE
A-11



Mid-Elevation Zone 3 (Core)

Notes: 1) Basis of elevations is NAVD 1988. Reservoir level data were corrected from 1929 to 1988 datum by adding 2.80 feet
2) Some data not plotted due to erroneously low values-see tables
3) W:\Geology\DAMS\Annual Dam Safety Reports\DSOD\anderson dam \2008\72-9-12_08.grf

DATE	12/30/08
DESIGN	JLN
DRAWN	JLN
CHECKED	RLV

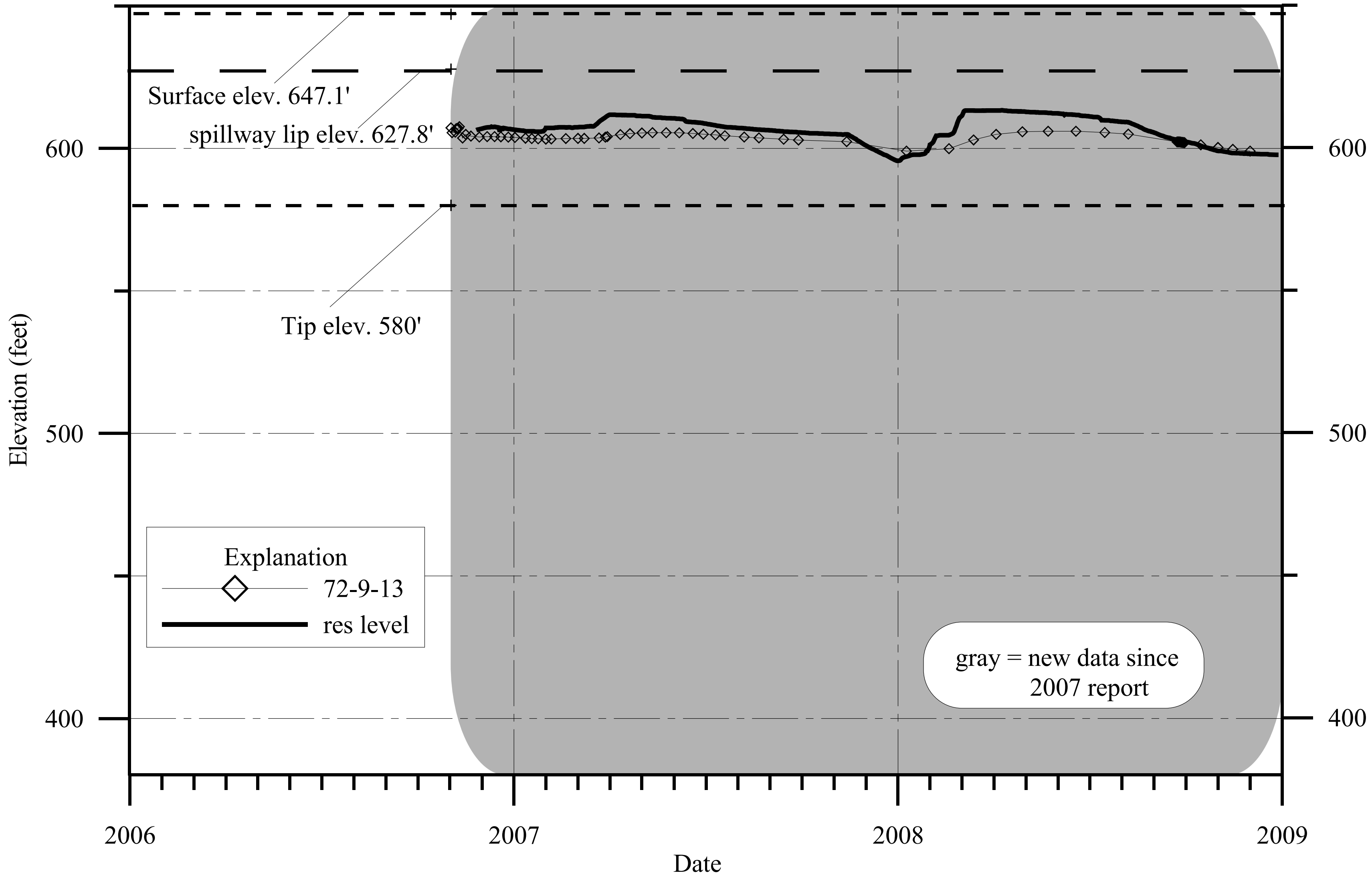
Santa Clara Valley Water District

72-9-12

Anderson Dam No. 72-9

SCALE as-shown

FIGURE A-12



Upper-Elevation Zone 3 (Core)

Notes: 1) Basis of elevations is NAVD 1988. Reservoir level data were corrected from 1929 to 1988 datum by adding 2.80 feet
2) Some data not plotted due to erroneously low values-see tables
3) W:\Geology\DAMS\Annual Dam Safety Reports\DSOD\anderson dam \2008\72-9-13_08.grf

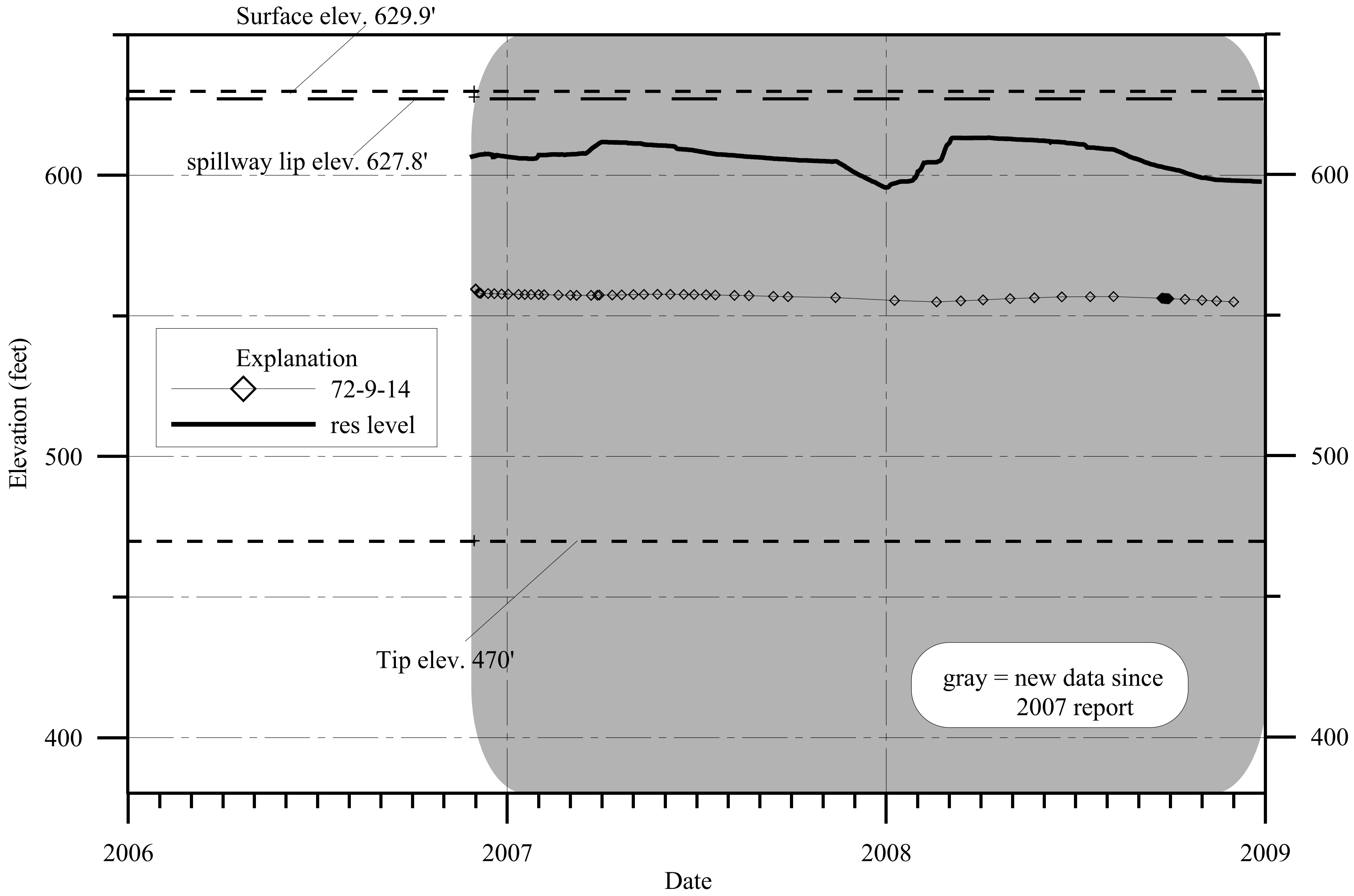
DATE 12/30/08
DESIGN JLN
DRAWN JLN
CHECKED RLV

Santa Clara Valley Water District

72-9-13

Anderson Dam No. 72-9

SCALE as-shown
FIGURE A-13



Lower-Elevation Zone 3 (Core)

Notes: 1) Basis of elevations is NAVD 1988. Reservoir level data were corrected from 1929 to 1988 datum by adding 2.80 feet
2) Some data not plotted due to erroneously low values-see tables
3) W:\Geology\DAMS\Annual Dam Safety Reports\DSOD\anderson dam \2008\72-9-14_08.grf

DATE 12/30/08
DESIGN JLN
DRAWN JLN
CHECKED RLV

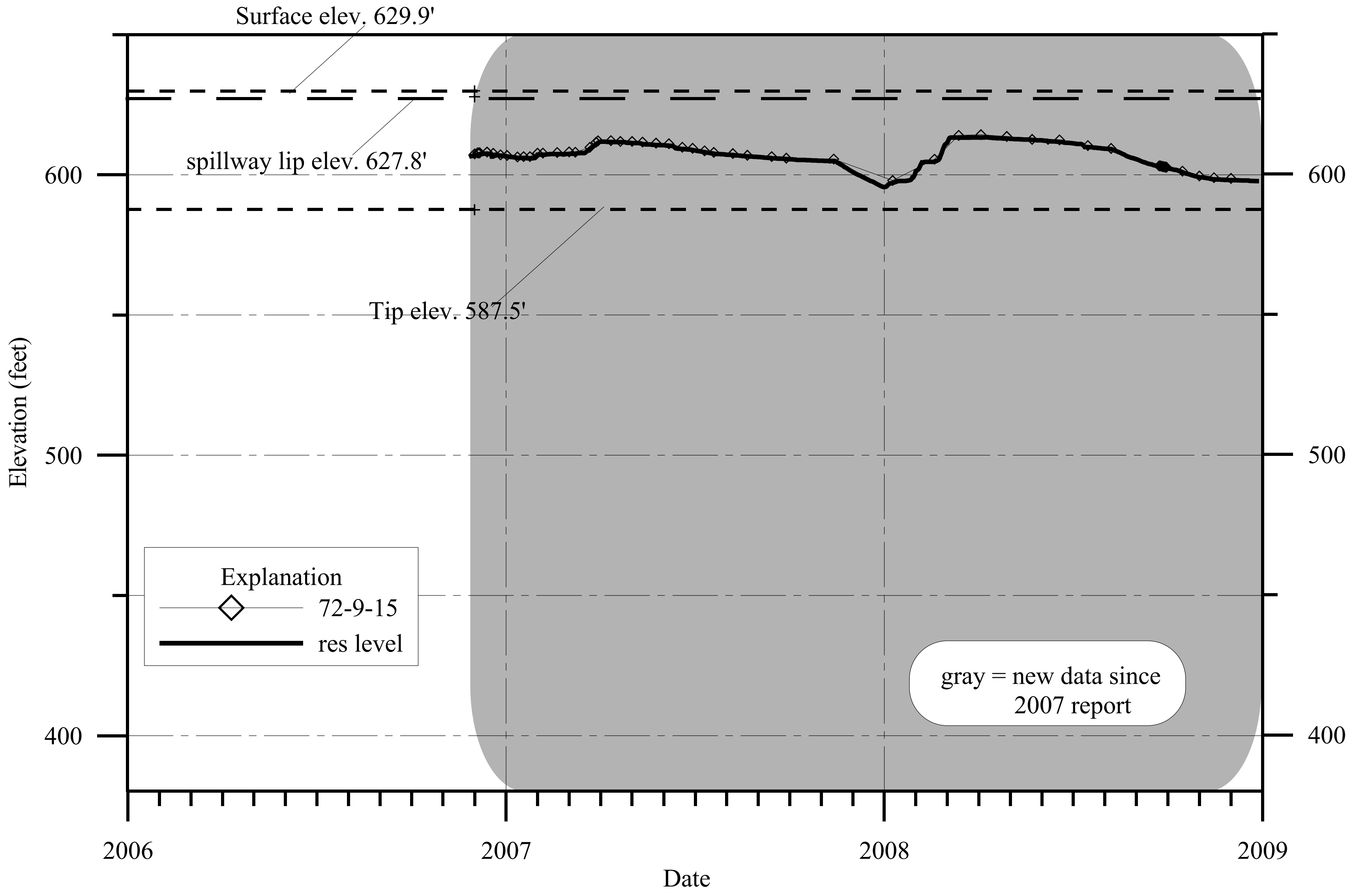
Santa Clara Valley Water District

72-9-14

Anderson Dam No. 72-9

SCALE as-shown

FIGURE A-14



Upstream Transition/Zone 3 (Core)

Notes: 1) Basis of elevations is NAVD 1988. Reservoir level data were corrected from 1929 to 1988 datum by adding 2.80 feet
2) Some data not plotted due to erroneously low values-see tables
3) W:\Geology\DAMS\Annual Dam Safety Reports\DSOD\anderson dam \2008\72-9-15_08.grf

DATE	12/30/08
DESIGN	JLN
DRAWN	JLN
CHECKED	RLV

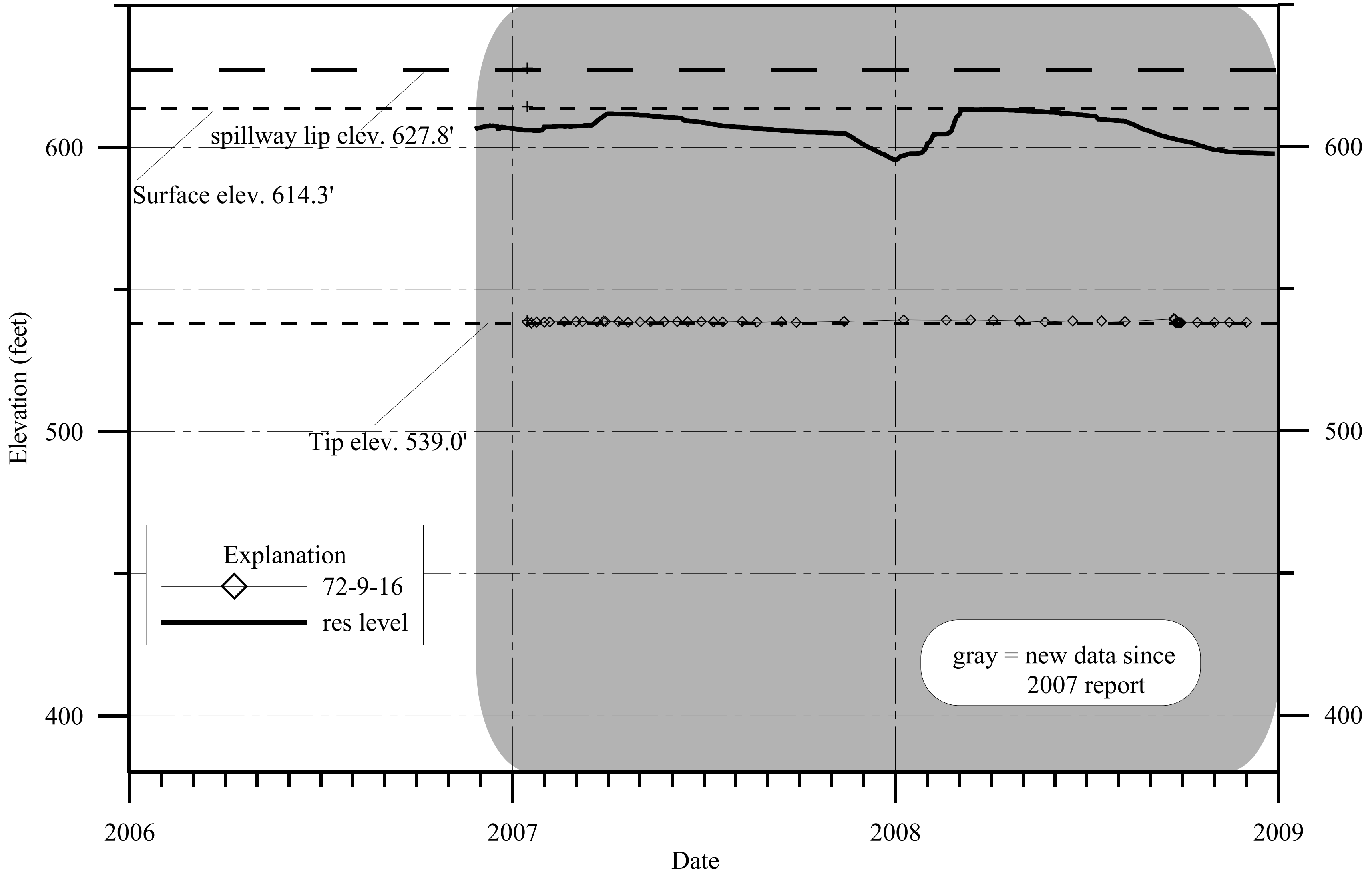
Santa Clara Valley Water District

72-9-15

Anderson Dam No. 72-9

SCALE as-shown

FIGURE A-15



Upstream Transition/Zone 3 (Core)

Notes: 1) Basis of elevations is NAVD 1988. Reservoir level data were corrected from 1929 to 1988 datum by adding 2.80 feet
2) Some data not plotted due to erroneously low values-see tables
3) W:\Geology\DAMS\Annual Dam Safety Reports\DSOD\anderson dam \2008\72-9-16_08.grf

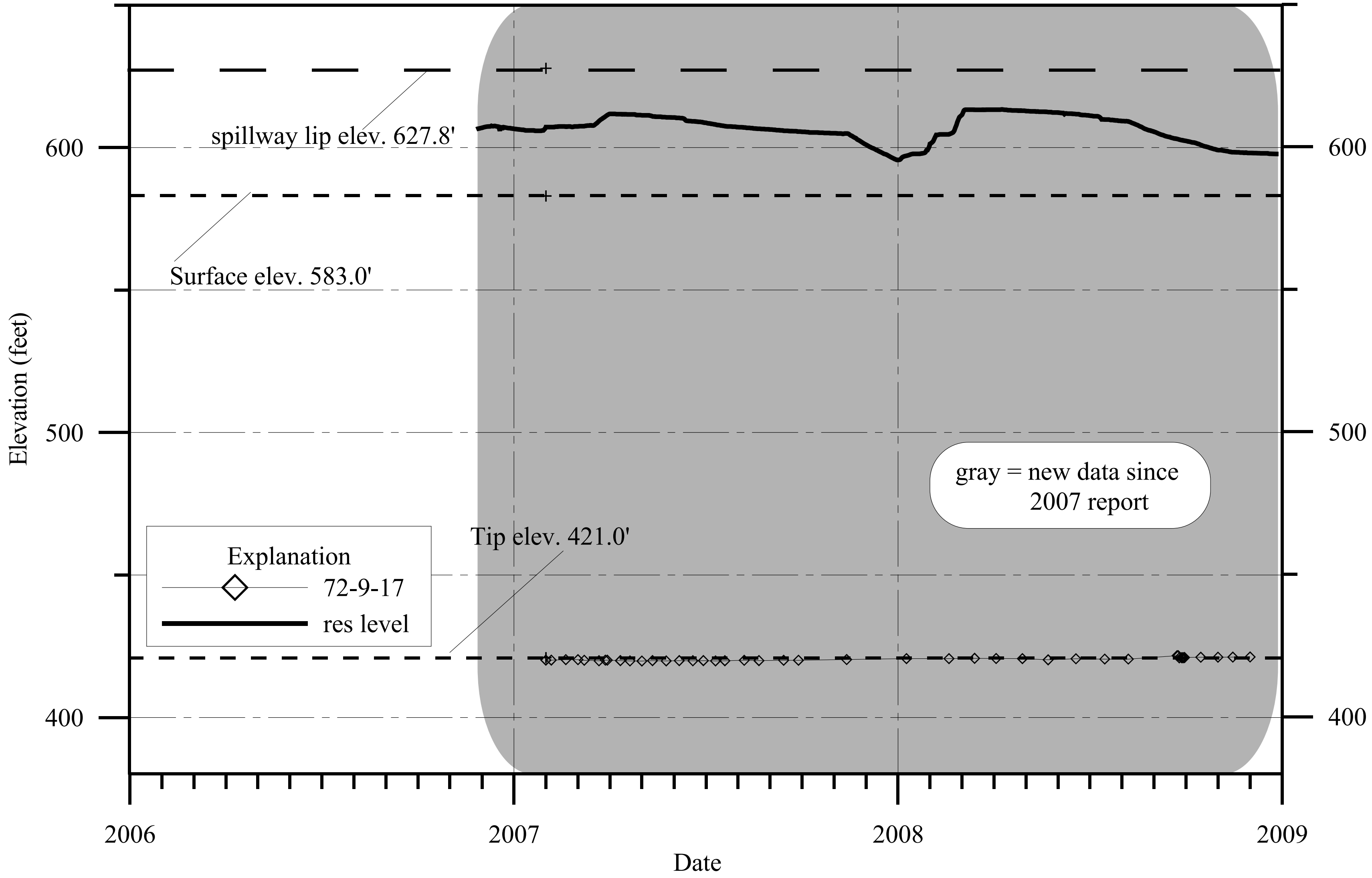
DATE 12/30/08
DESIGN JLN
DRAWN JLN
CHECKED RLV

Santa Clara Valley Water District

72-9-16

Anderson Dam No. 72-9

SCALE as-shown
FIGURE A-16



Downstream Transition/Zone 3 (Core)

Notes: 1) Basis of elevations is NAVD 1988. Reservoir level data were corrected from 1929 to 1988 datum by adding 2.80 feet
2) Some data not plotted due to erroneously low values-see tables
3) W:\Geology\DAMS\Annual Dam Safety Reports\DSOD\anderson dam \2008\72-9-17_08.grf

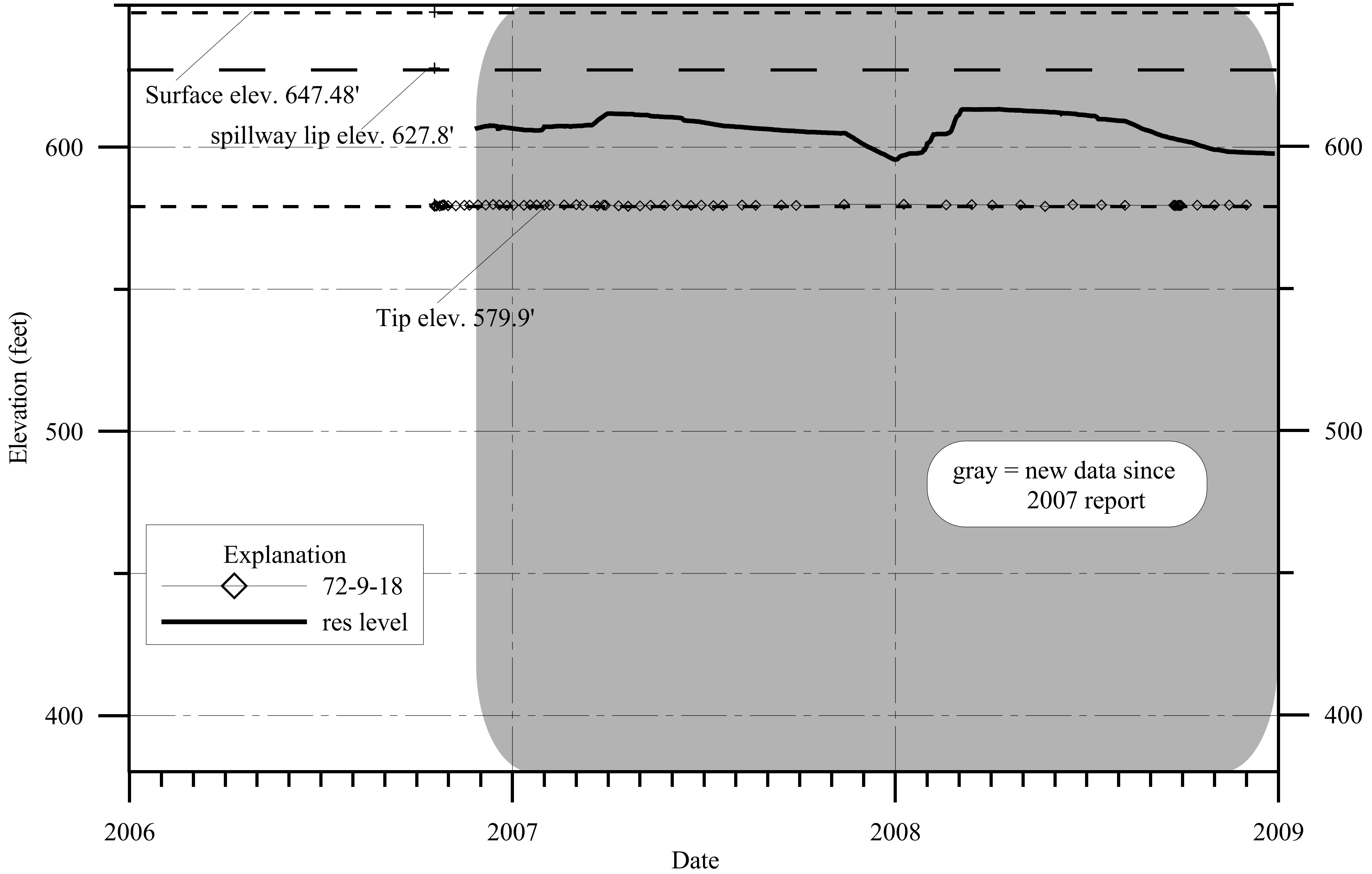
DATE 12/30/08
DESIGN JLN
DRAWN JLN
CHECKED RLV

Santa Clara Valley Water District

72-9-17

Anderson Dam No. 72-9

SCALE as-shown
FIGURE A-17



Left Abutment Foundation (Core)

Notes: 1) Basis of elevations is NAVD 1988. Reservoir level data were corrected from 1929 to 1988 datum by adding 2.80 feet
2) Some data not plotted due to erroneously low values-see tables
3) W:\Geology\DAMS\Annual Dam Safety Reports\DSOD\anderson dam \2008\72-9-18_08.grf

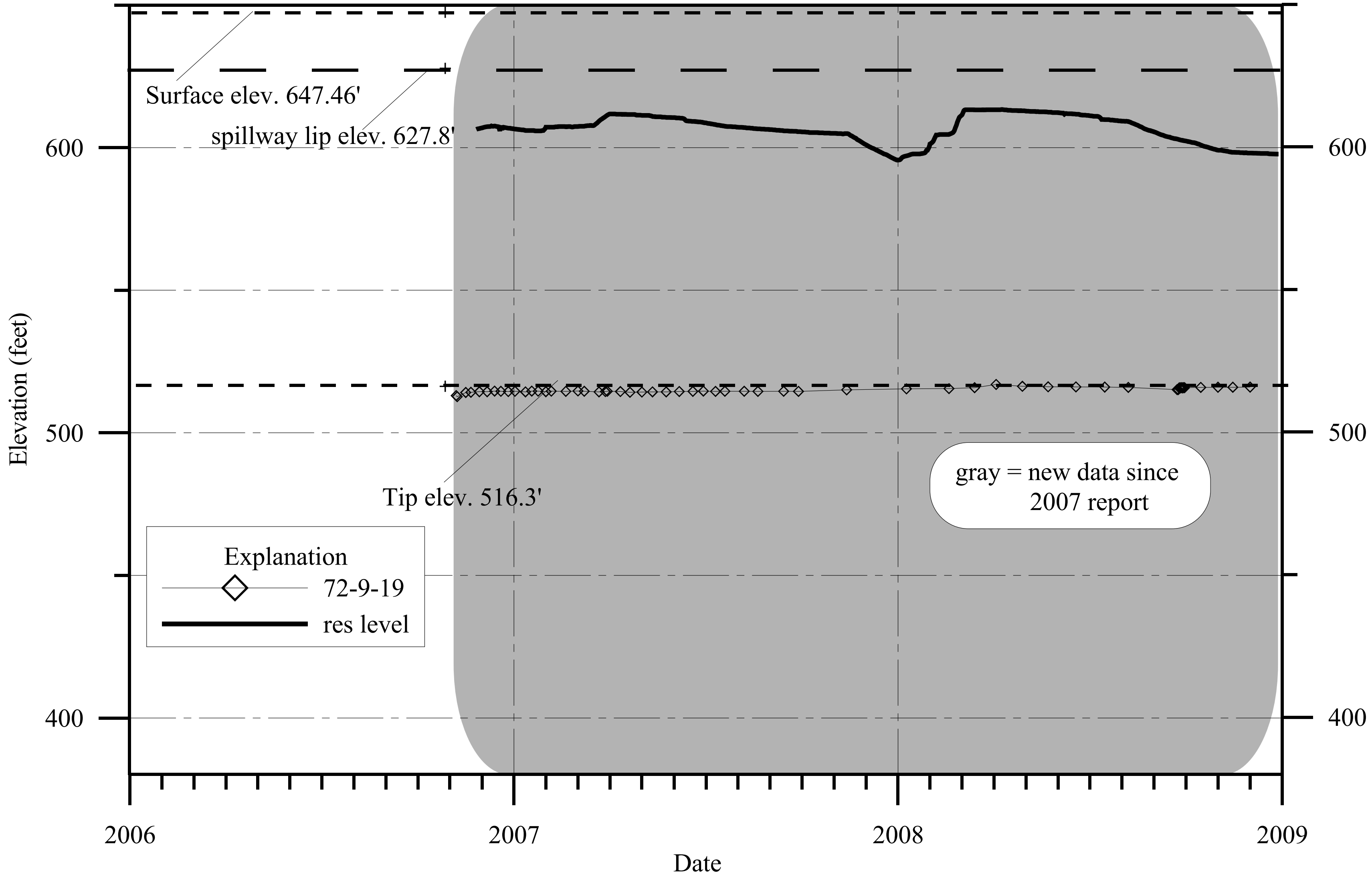
DATE 12/30/08
DESIGN JLN
DRAWN JLN
CHECKED RLV

Santa Clara Valley Water District

72-9-18

Anderson Dam No. 72-9

SCALE as-shown
FIGURE A-18



Left Abutment Foundation (Core)

Notes: 1) Basis of elevations is NAVD 1988. Reservoir level data were corrected from 1929 to 1988 datum by adding 2.80 feet
2) Some data not plotted due to erroneously low values-see tables
3) W:\Geology\DAMS\Annual Dam Safety Reports\DSOD\anderson dam \2008\72-9-19_08.grf

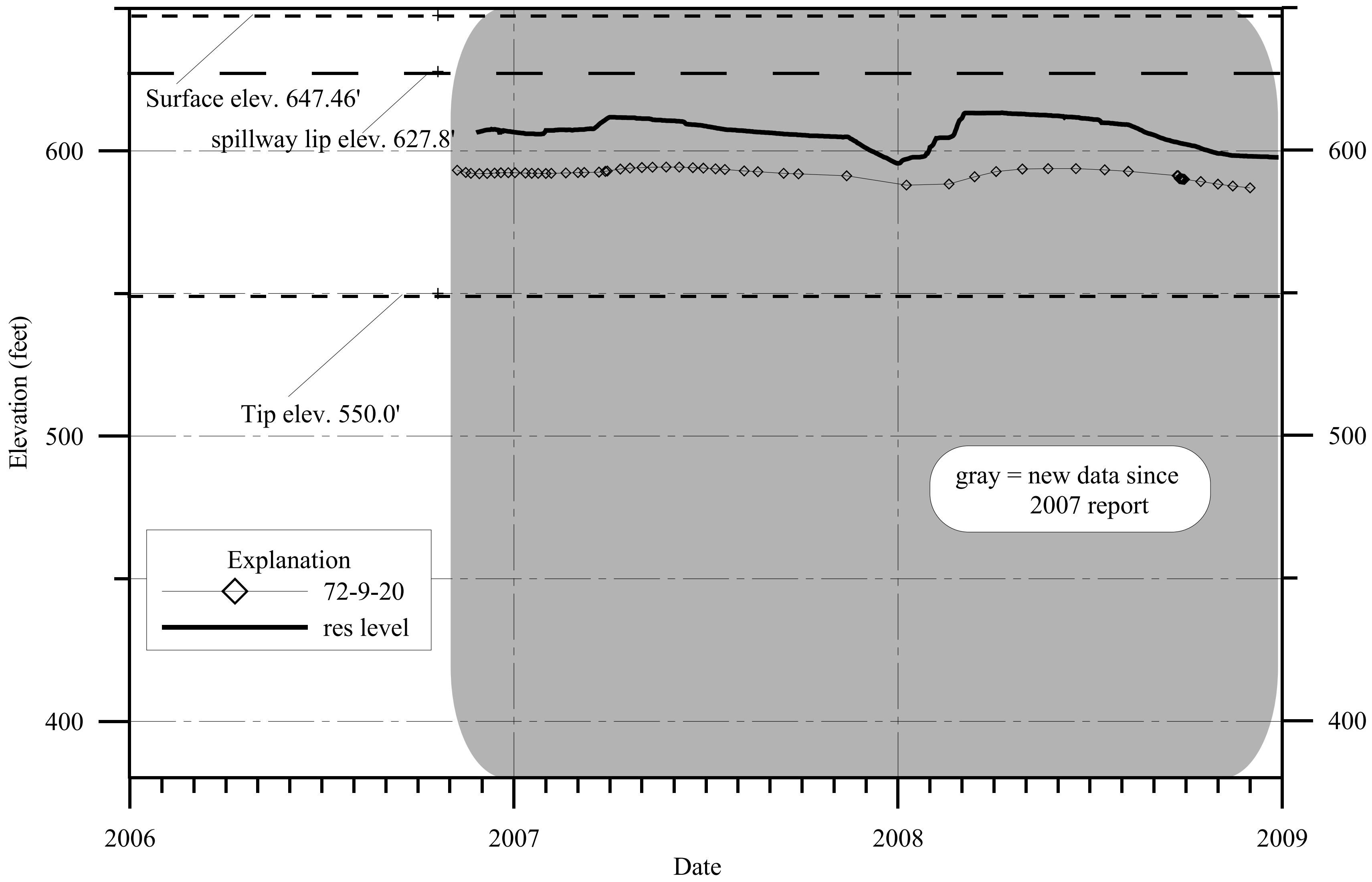
DATE 12/30/08
DESIGN JLN
DRAWN JLN
CHECKED RLV

Santa Clara Valley Water District

72-9-19

Anderson Dam No. 72-9

SCALE as-shown
FIGURE A-19



Left Abutment Core

Notes: 1) Basis of elevations is NAVD 1988. Reservoir level data were corrected from 1929 to 1988 datum by adding 2.80 feet
2) Some data not plotted due to erroneously low values-see tables
3) W:\Geology\DAMS\Annual Dam Safety Reports\DSOD\anderson dam \2008\72-9-20_08.grf

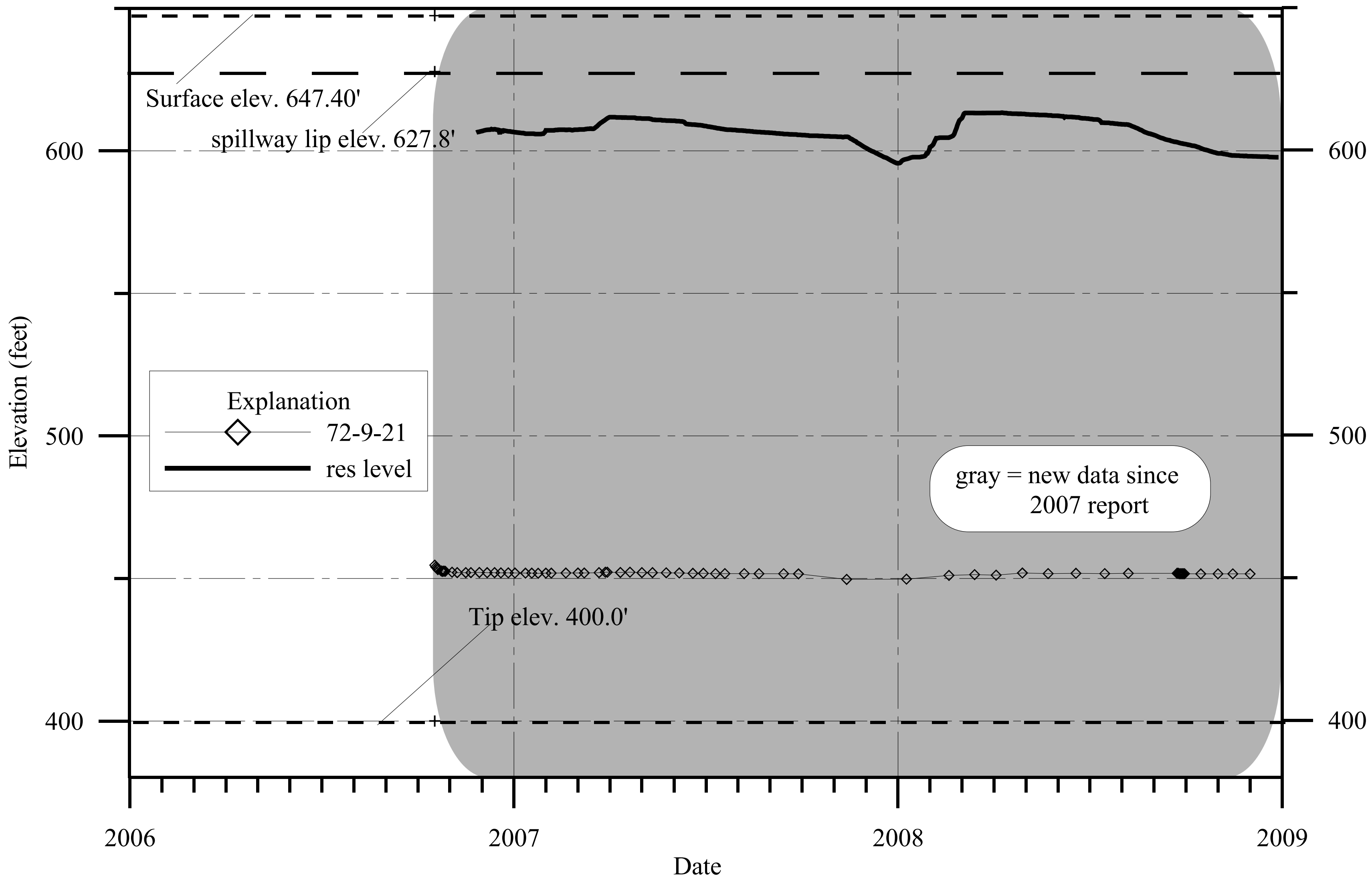
DATE 12/30/08
DESIGN JLN
DRAWN JLN
CHECKED RLV

Santa Clara Valley Water District

72-9-20

Anderson Dam No. 72-9

SCALE as-shown
FIGURE A-20



Lower Elevation Core

Notes: 1) Basis of elevations is NAVD 1988. Reservoir level data were corrected from 1929 to 1988 datum by adding 2.80 feet
2) Some data not plotted due to erroneously low values-see tables
3) W:\Geology\DAMS\Annual Dam Safety Reports\DSOD\anderson dam \2008\72-9-21_08.grf

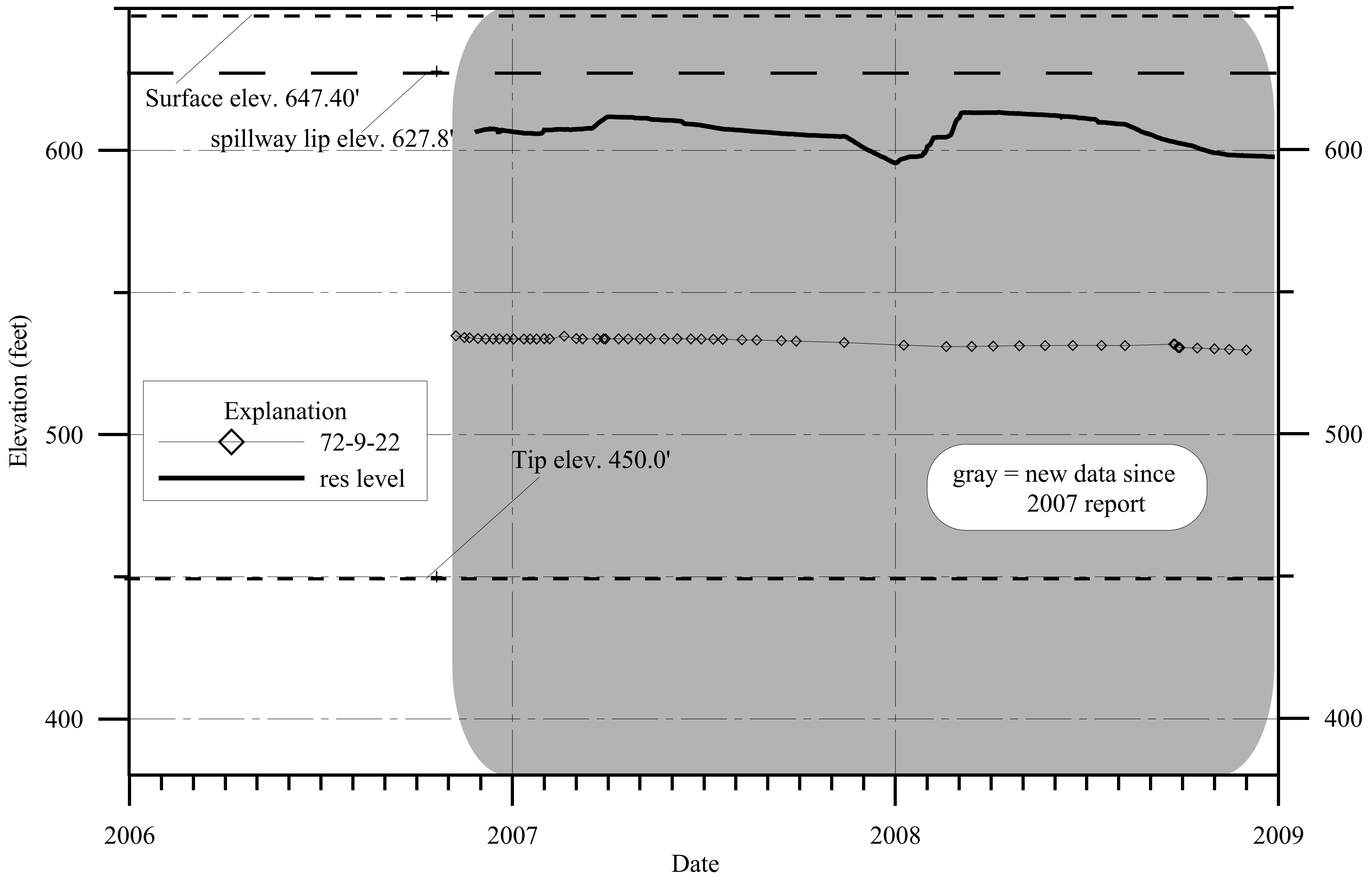
DATE 12/30/08
DESIGN JLN
DRAWN JLN
CHECKED RLV

Santa Clara Valley Water District

72-9-21

Anderson Dam No. 72-9

SCALE as-shown
FIGURE A-21



Lower Elevation Core

Notes: 1) Basis of elevations is NAVD 1988. Reservoir level data were corrected from 1929 to 1988 datum by adding 2.80 feet
2) Some data not plotted due to erroneously low values-see tables
3) W:\Geology\DAMS\Annual Dam Safety Reports\DSOD\anderson dam \2008\72-9-22_08.grf

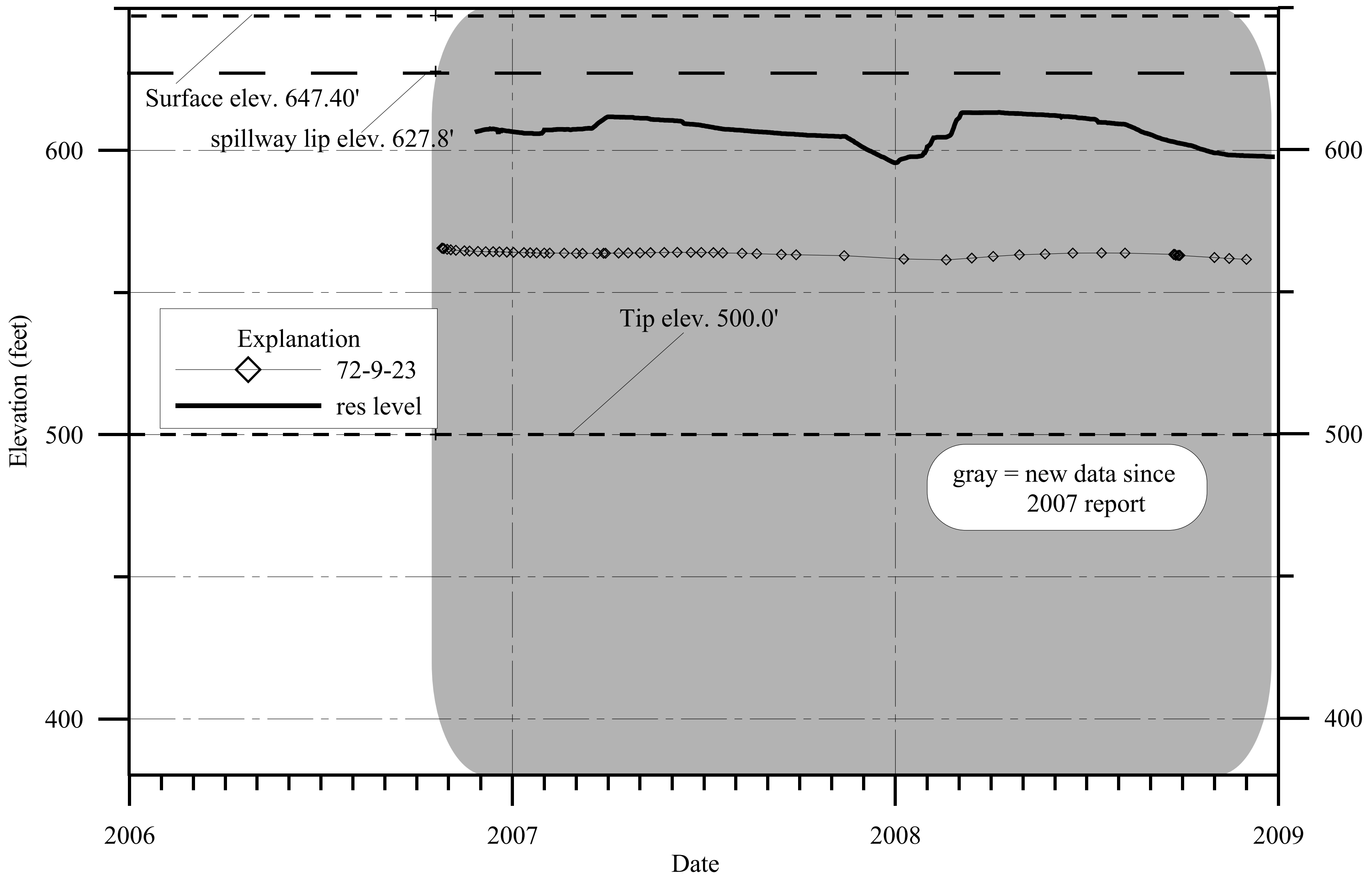
DATE 12/30/08
DESIGN JLN
DRAWN JLN
CHECKED RLV

Santa Clara Valley Water District

72-9-22

Anderson Dam 72-9

SCALE as-shown
FIGURE A-22



Mid-Elevation Core

Notes: 1) Basis of elevations is NAVD 1988. Reservoir level data were corrected from 1929 to 1988 datum by adding 2.80 feet
2) Some data not plotted due to erroneously low values-see tables
3) W:\Geology\DAMS\Annual Dam Safety Reports\DSOD\anderson dam \2008\72-9-23_08.grf

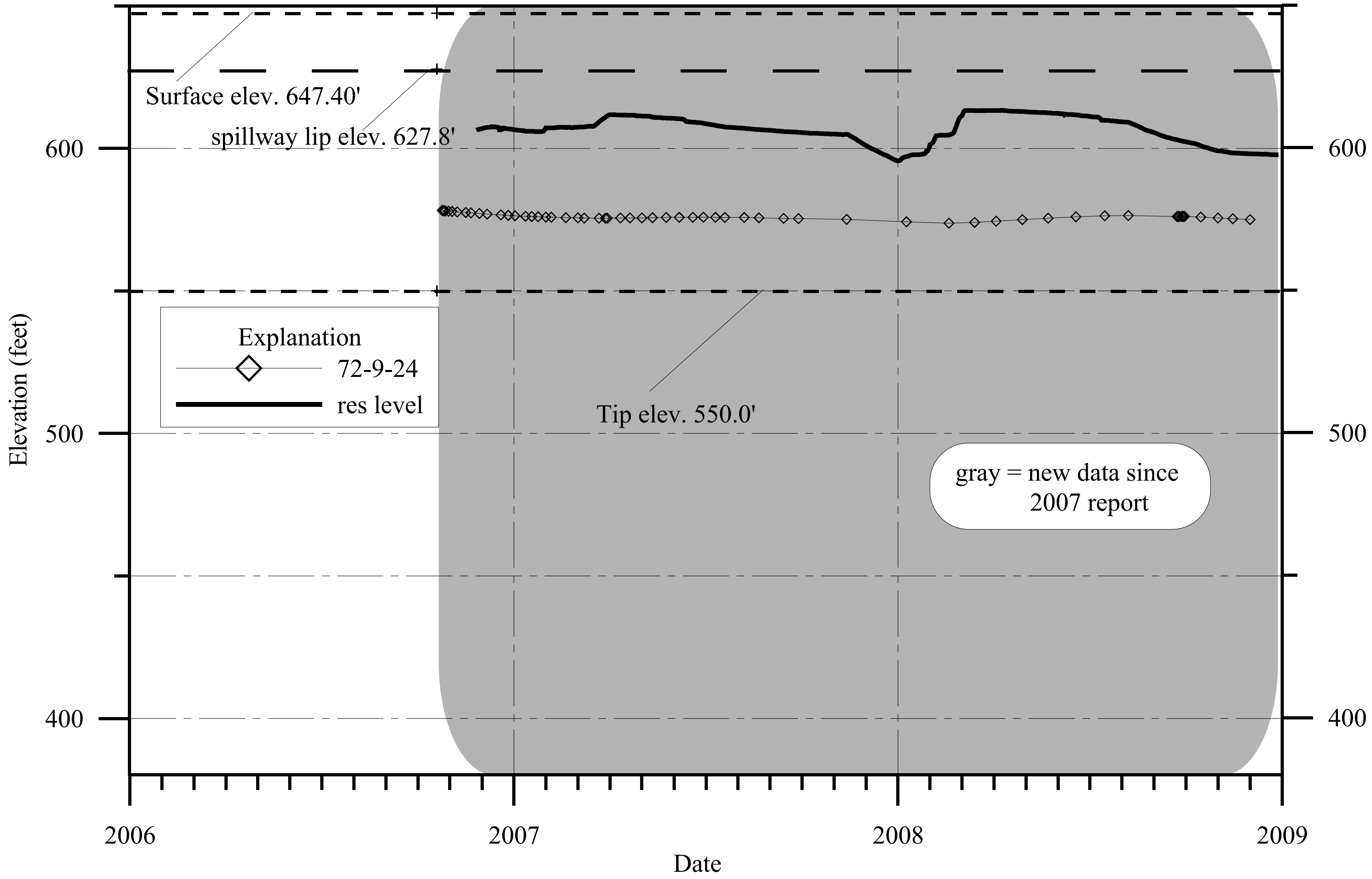
DATE 12/30/08
DESIGN JLN
DRAWN JLN
CHECKED RLV

Santa Clara Valley Water District

72-9-23

Anderson Dam No. 72-9

SCALE as-shown
FIGURE A-23



Upper-Elevation Core

Notes: 1) Basis of elevations is NAVD 1988. Reservoir level data were corrected from 1929 to 1988 datum by adding 2.80 feet
2) Some data not plotted due to erroneously low values-see tables
3) W:\Geology\DAMS\Annual Dam Safety Reports\DSOD\anderson dam \2008\72-9-24_08.grf

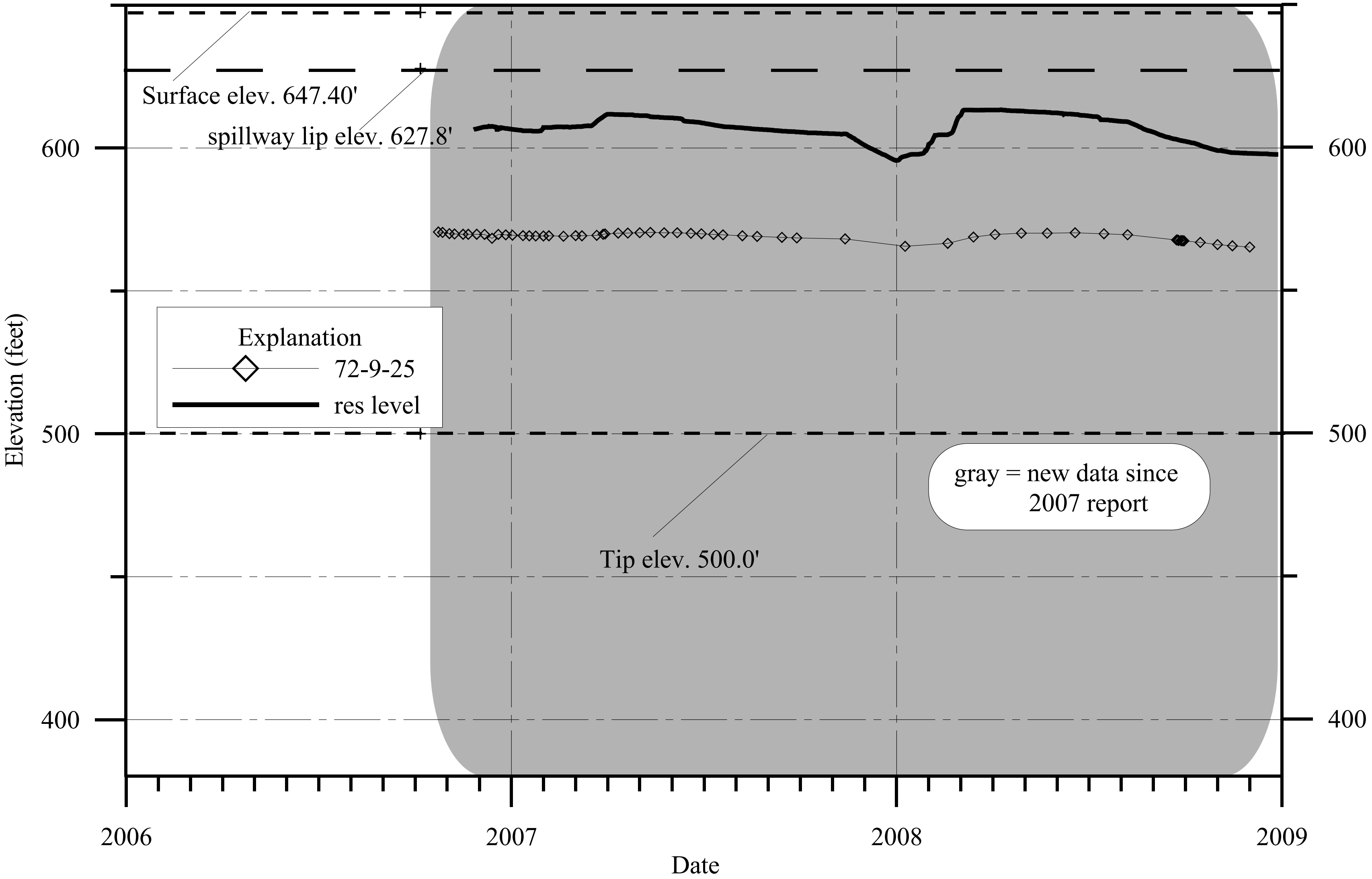
DATE 12/30/08
DESIGN JLN
DRAWN JLN
CHECKED RLV

Santa Clara Valley Water District

72-9-24

Anderson Dam No. 72-9

SCALE as-shown
FIGURE A-24



Right Abutment Foundation

Notes: 1) Basis of elevations is NAVD 1988. Reservoir level data were corrected from 1929 to 1988 datum by adding 2.80 feet
2) Some data not plotted due to erroneously low values-see tables
3) W:\Geology\DAMS\Annual Dam Safety Reports\DSOD\anderson dam \2008\72-9-25_08.grf

DATE	12/30/08
DESIGN	JLN
DRAWN	JLN
CHECKED	RLV

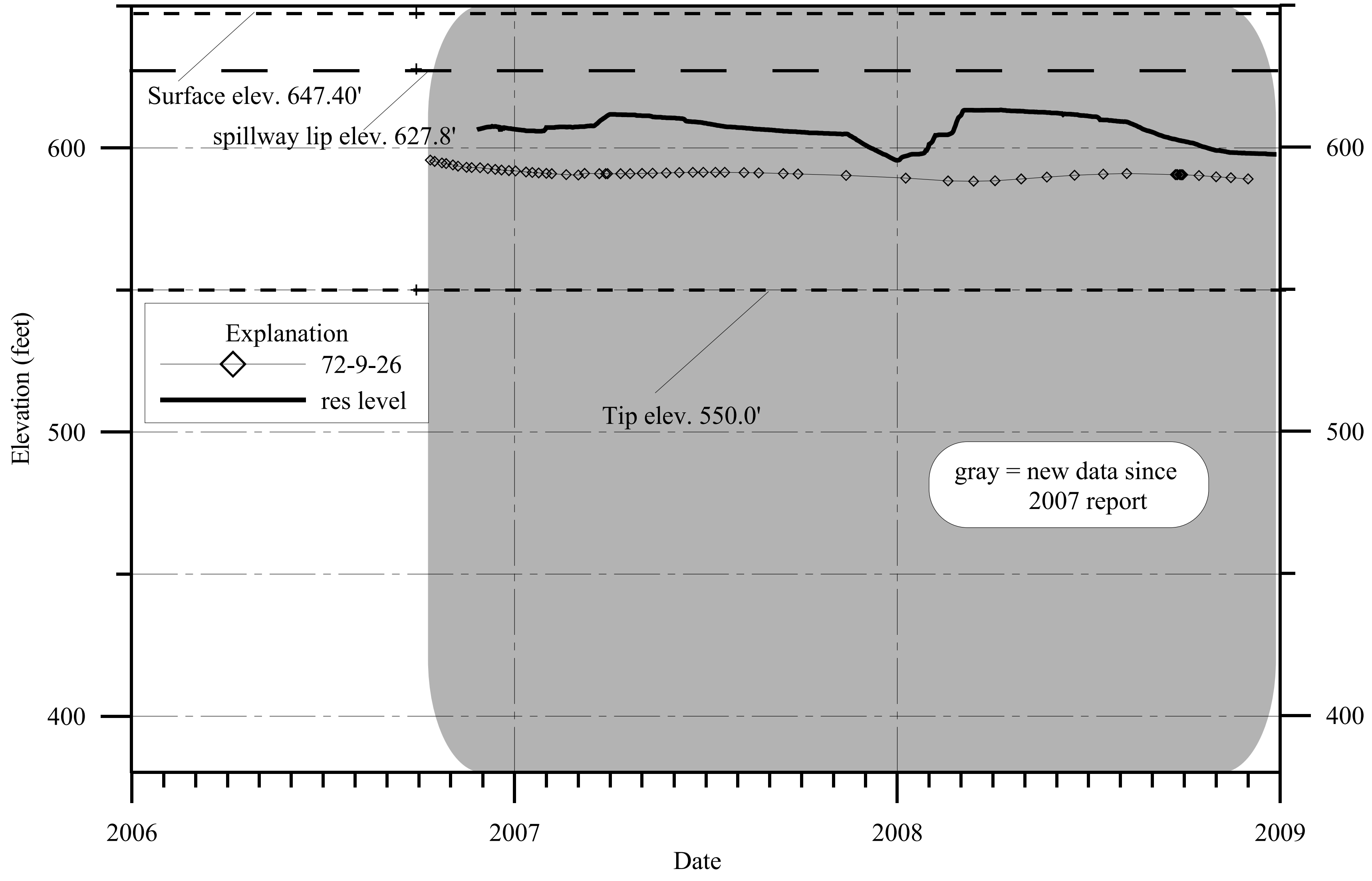
Santa Clara Valley Water District

72-9-25

Anderson Dam No. 72-9

SCALE as-shown

FIGURE A-25



Right Abutment Core (Zone 3)

Notes: 1) Basis of elevations is NAVD 1988. Reservoir level data were corrected from 1929 to 1988 datum by adding 2.80 feet
2) Some data not plotted due to erroneously low values-see tables
3) W:\Geology\DAMS\Annual Dam Safety Reports\DSOD\anderson dam \2008\72-9-26_08.grf

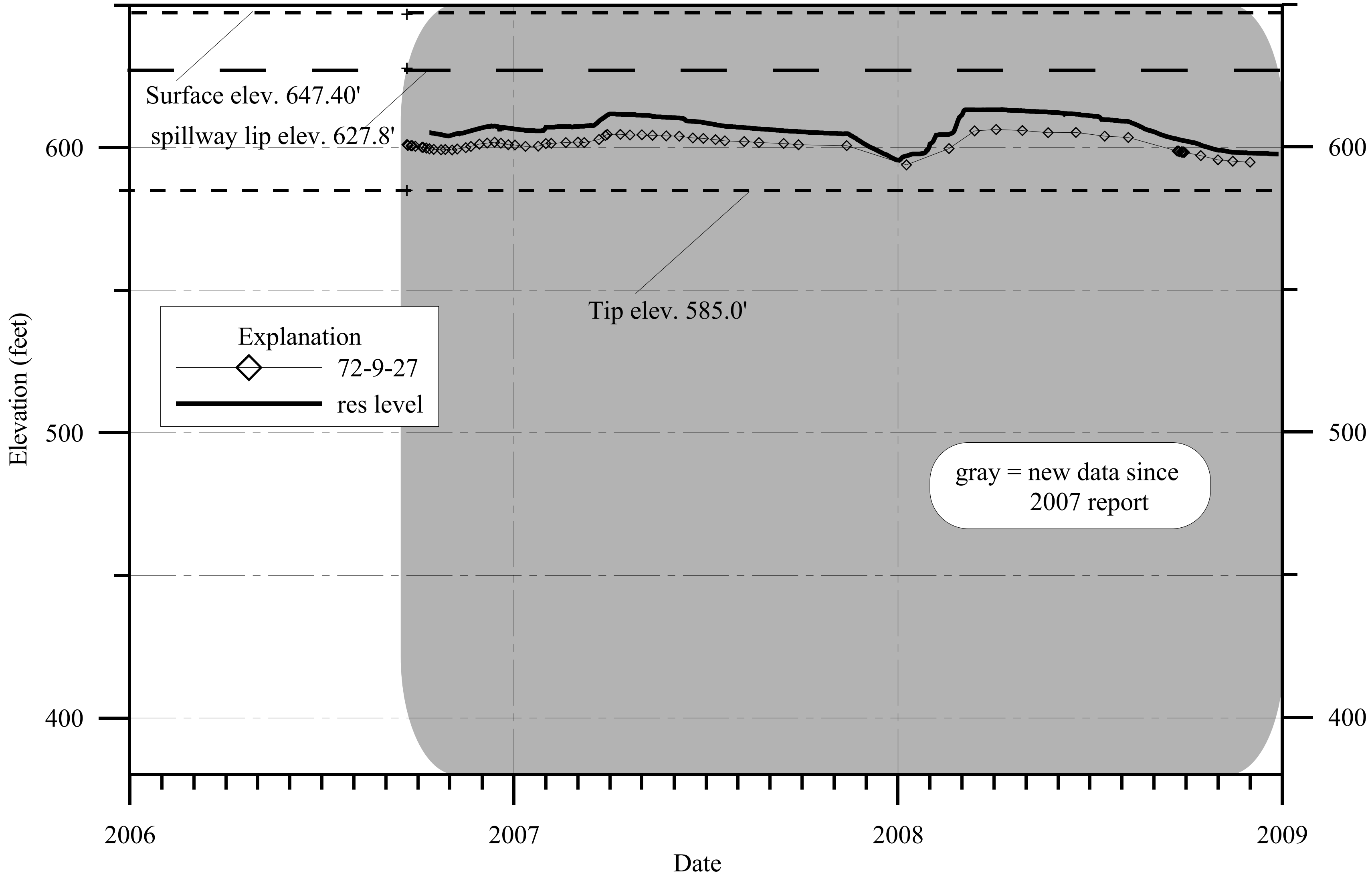
DATE 12/30/08
DESIGN JLN
DRAWN JLN
CHECKED RLV

Santa Clara Valley Water District

72-9-26

Anderson Dam No. 72-9

SCALE as-shown
FIGURE A-26



Right Abutment Foundation

Notes: 1) Basis of elevations is NAVD 1988. Reservoir level data were corrected from 1929 to 1988 datum by adding 2.80 feet
2) Some data not plotted due to erroneously low values-see tables
3) W:\Geology\DAMS\Annual Dam Safety Reports\DSOD\anderson dam \2008\72-9-27_08.grf

DATE 12/30/08
DESIGN JLN
DRAWN JLN
CHECKED RLV

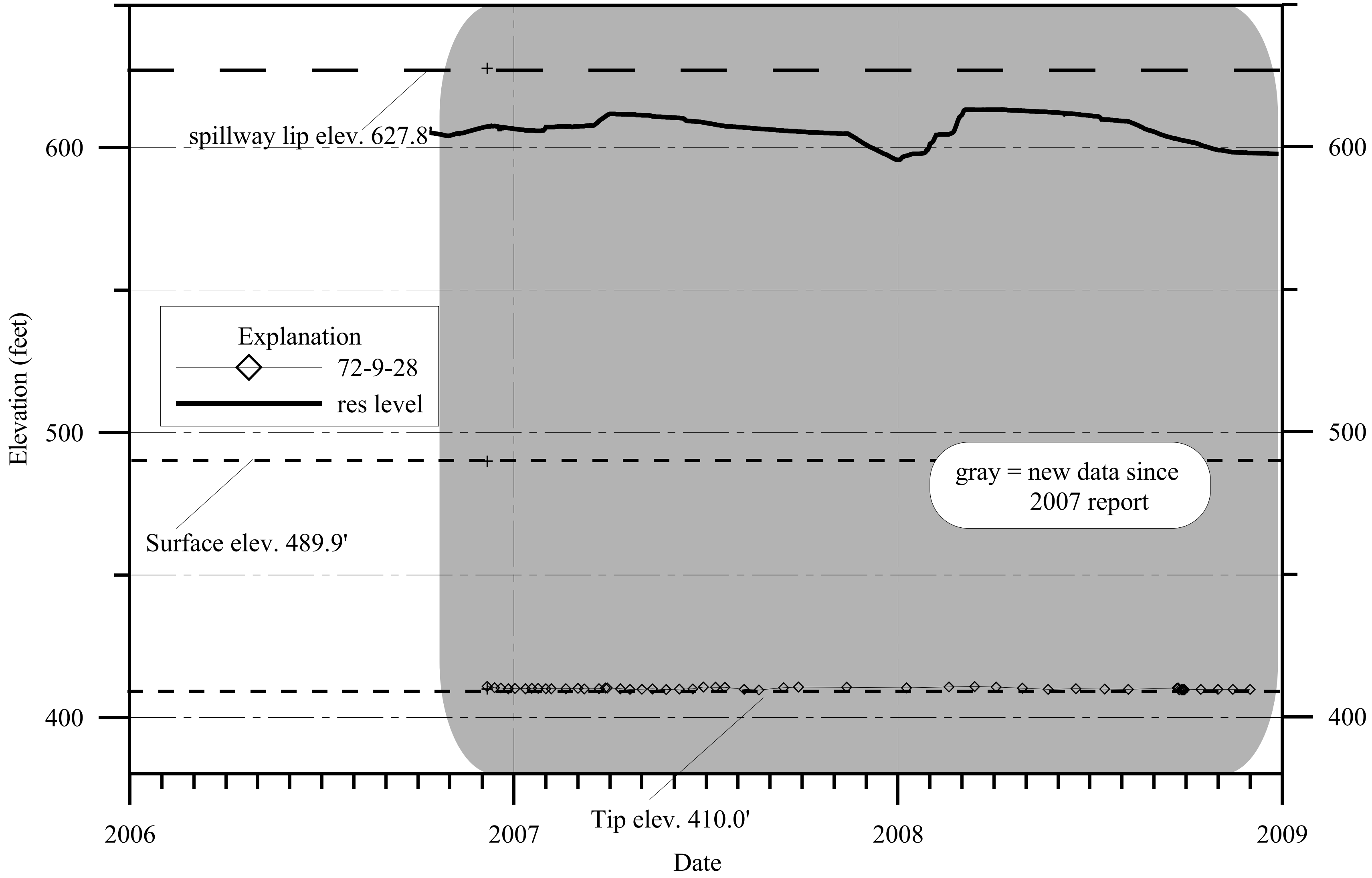
Santa Clara Valley Water District

72-9-27

Anderson Dam No. 72-9

SCALE as-shown

FIGURE A-27



Downstream Foundation

Notes: 1) Basis of elevations is NAVD 1988. Reservoir level data were corrected from 1929 to 1988 datum by adding 2.80 feet
2) Some data not plotted due to erroneously low values-see tables
3) W:\Geology\DAMS\Annual Dam Safety Reports\DSOD\anderson dam \2008\72-9-27_08.grf

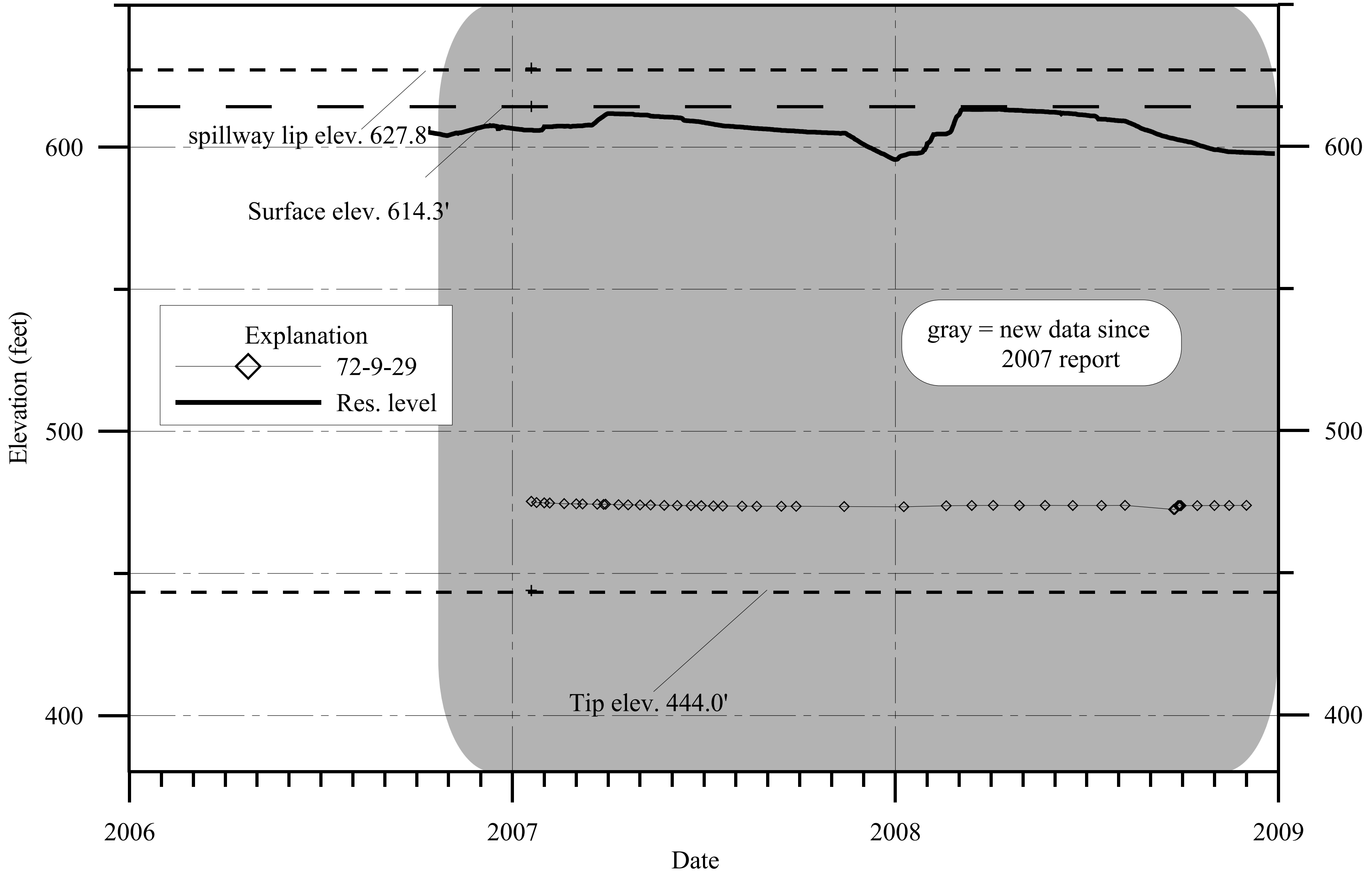
DATE 12/30/08
DESIGN JLN
DRAWN JLN
CHECKED RLV

Santa Clara Valley Water District

72-9-28

Anderson Dam No. 72-9

SCALE as-shown
FIGURE A-28



Downstream Lower Elevation Core

Notes: 1) Basis of elevations is NAVD 1988. Reservoir level data were corrected from 1929 to 1988 datum by adding 2.80 feet
2) Some data not plotted due to erroneously low values-see tables
3) W:\Geology\DAMS\Annual Dam Safety Reports\DSOD\anderson dam \2008\72-9-29_08.grf

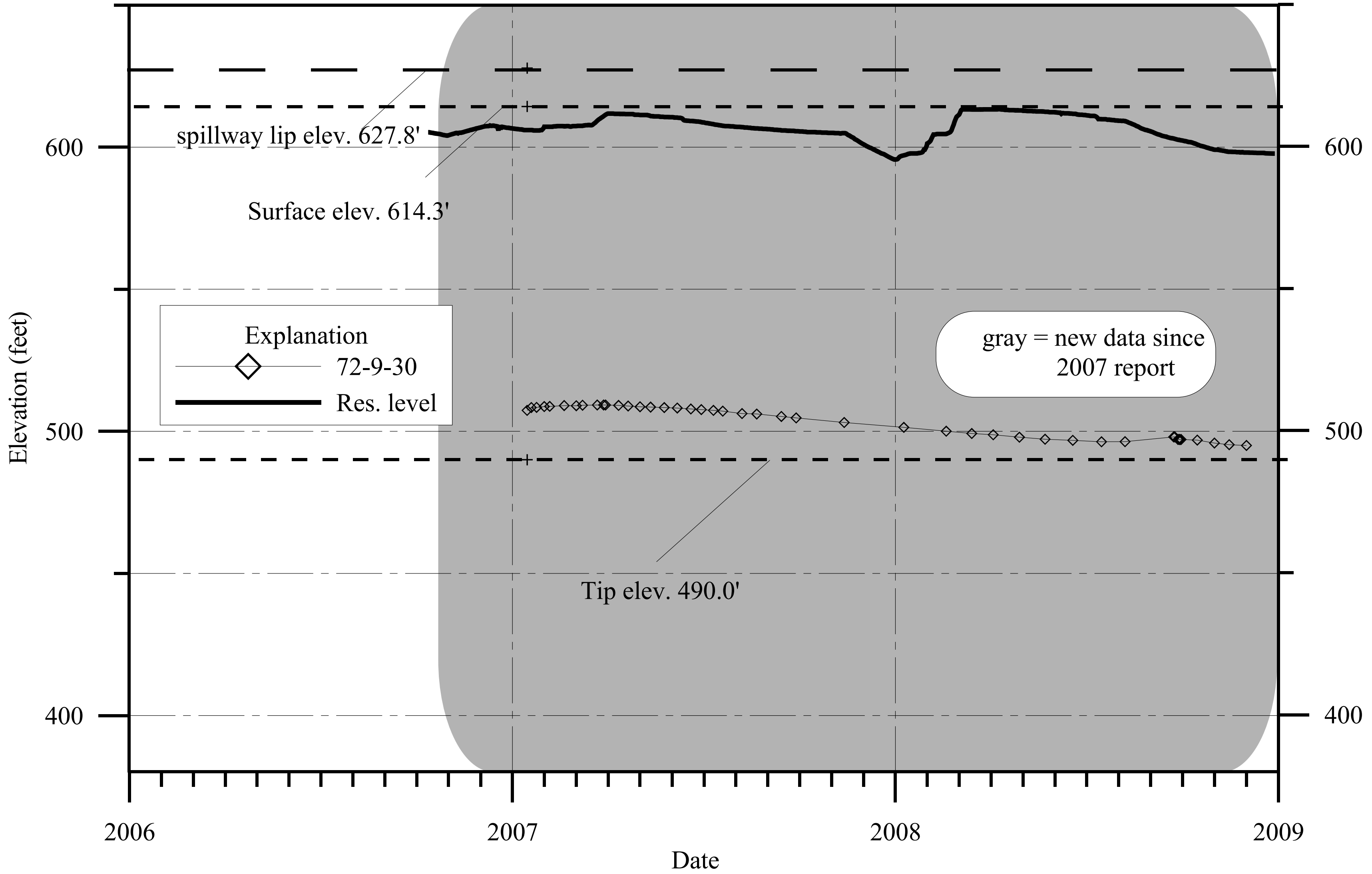
DATE	12/30/08
DESIGN	JLN
DRAWN	JLN
CHECKED	RLV

Santa Clara Valley Water District

72-9-29

Anderson Dam No. 72-9

SCALE	as-shown
FIGURE	A-29



Downstream Middle-Elevation Core

Notes: 1) Basis of elevations is NAVD 1988. Reservoir level data were corrected from 1929 to 1988 datum by adding 2.80 feet
2) Some data not plotted due to erroneously low values-see tables
3) W:\Geology\DAMS\Annual Dam Safety Reports\DSOD\anderson dam \2008\72-9-30_08.grf

DATE 12/30/08
DESIGN JLN
DRAWN JLN
CHECKED RLV

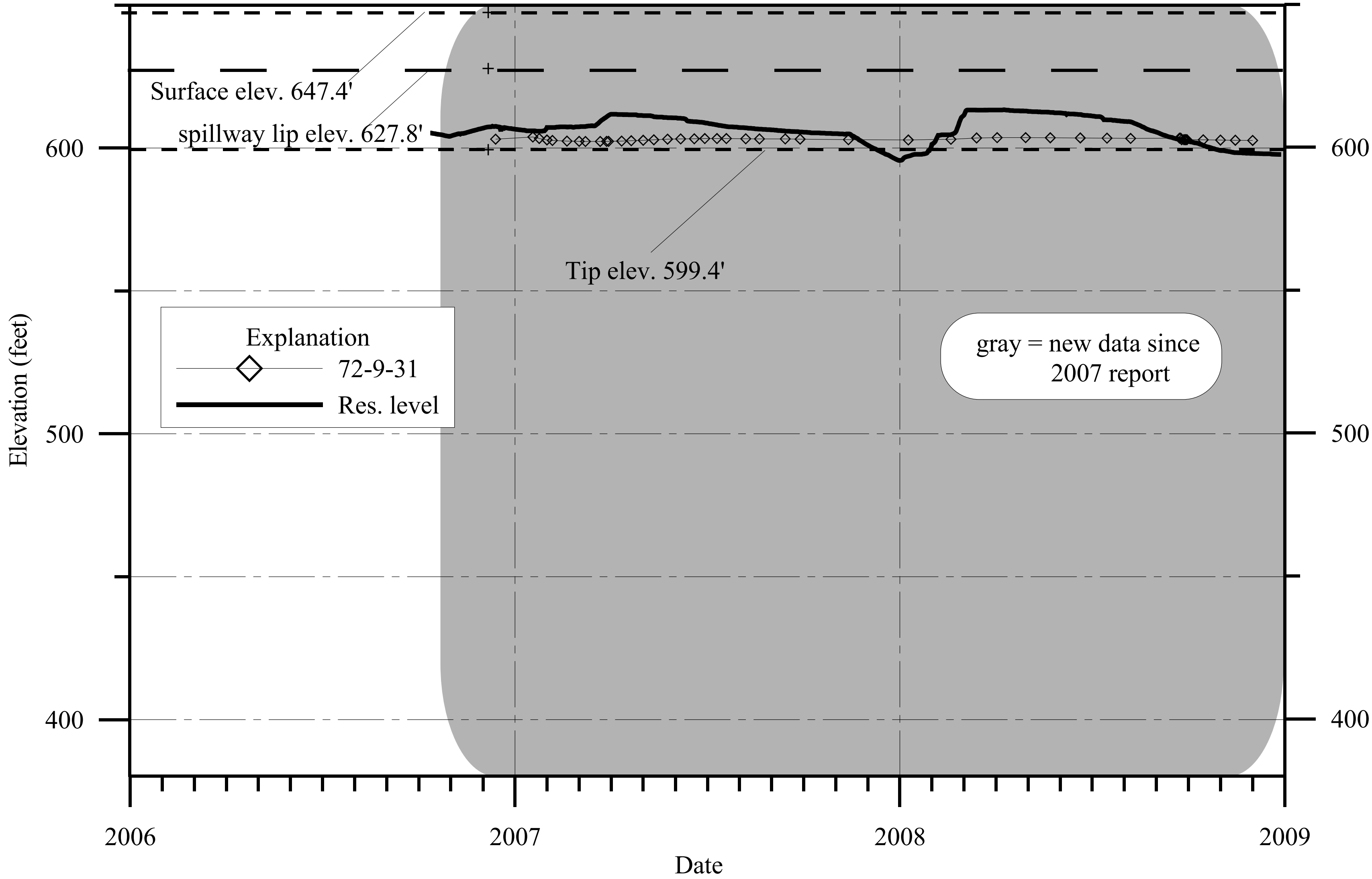
Santa Clara Valley Water District

72-9-30

Anderson Dam No. 72-9

SCALE as-shown

FIGURE A-30



Left Abutment Foundation (alluvium/colluvium)

Notes: 1) Basis of elevations is NAVD 1988. Reservoir level data were corrected from 1929 to 1988 datum by adding 2.80 feet
2) Some data not plotted due to erroneously low values-see tables
3) W:\Geology\DAMS\Annual Dam Safety Reports\DSOD\anderson dam \2008\72-9-31_08.grf

DATE	12/30/08
DESIGN	JLN
DRAWN	JLN
CHECKED	RLV

Santa Clara Valley Water District

72-9-31

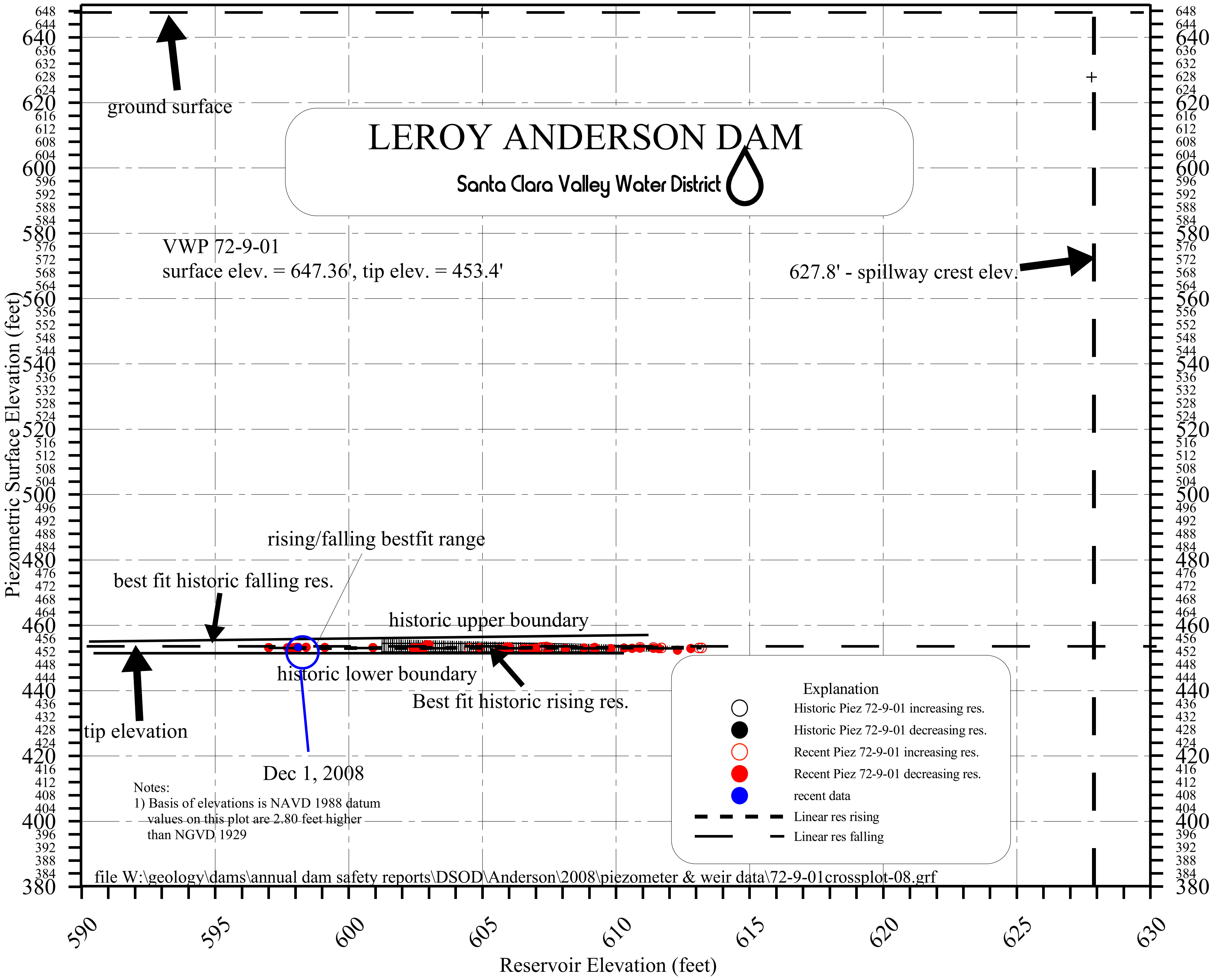
Anderson Dam No. 72-9

SCALE
as-shown

FIGURE
A-31

Appendix B – New Wire Piezometer Cross Plots

Figures B-1 through B-31 Cross Plots of Reservoir Elevations versus Vibrating Wire Piezometer Elevations at Leroy Anderson Dam



Notes:
1) Basis of elevations is NAVD 1988 datum values on this plot are 2.80 feet higher than NGVD 1929

file W:\geology\dams\annual dam safety reports\DSOD\Anderson\2008\piezometer & weir data\72-9-01crossplot-08.grf

Figure B-1. Cross-Plot of Reservoir Elevation vs. 72-9-01 Piezometer Data

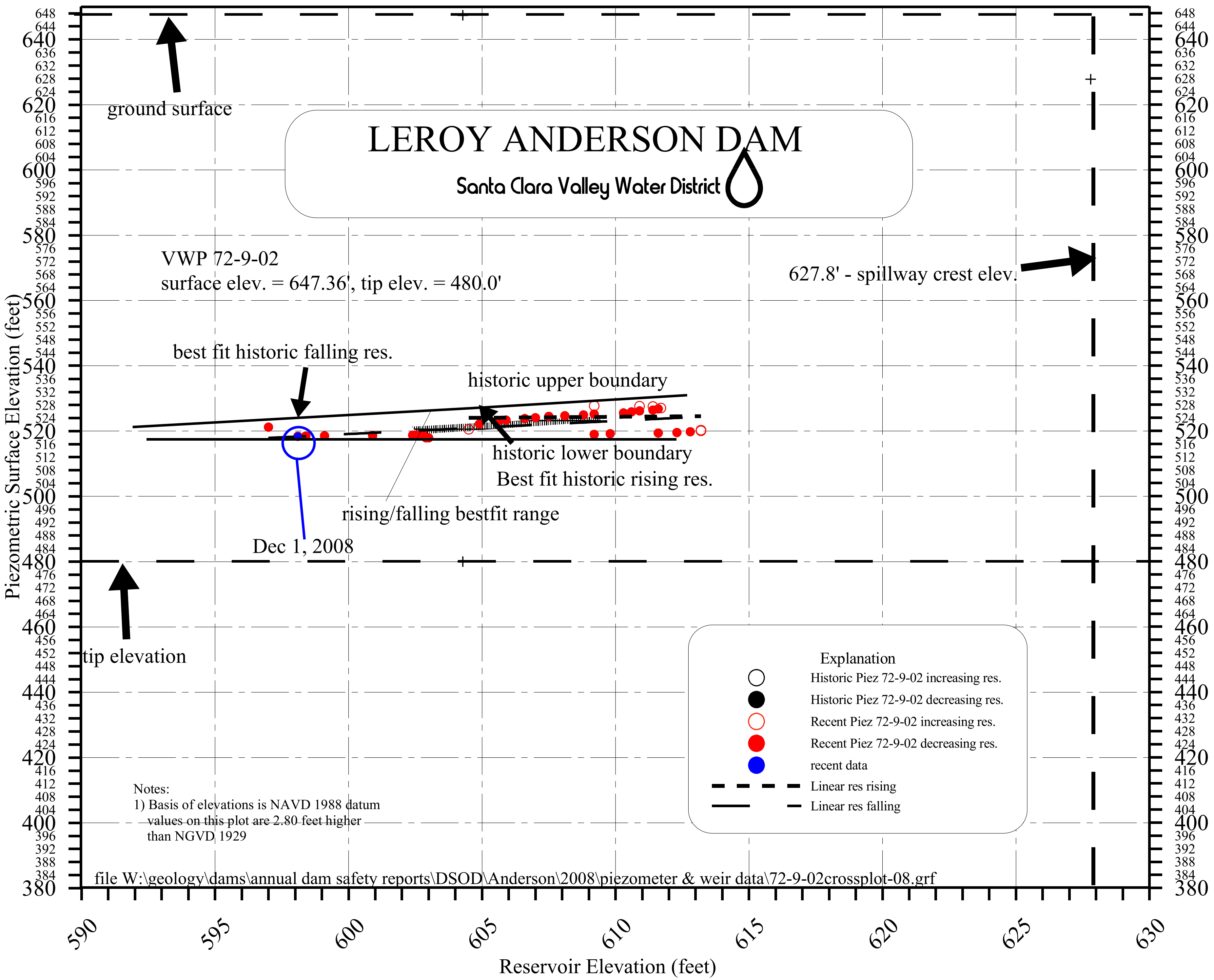


Figure B-2. Cross-Plot of Reservoir Elevation vs. 72-9-02 Piezometer Data

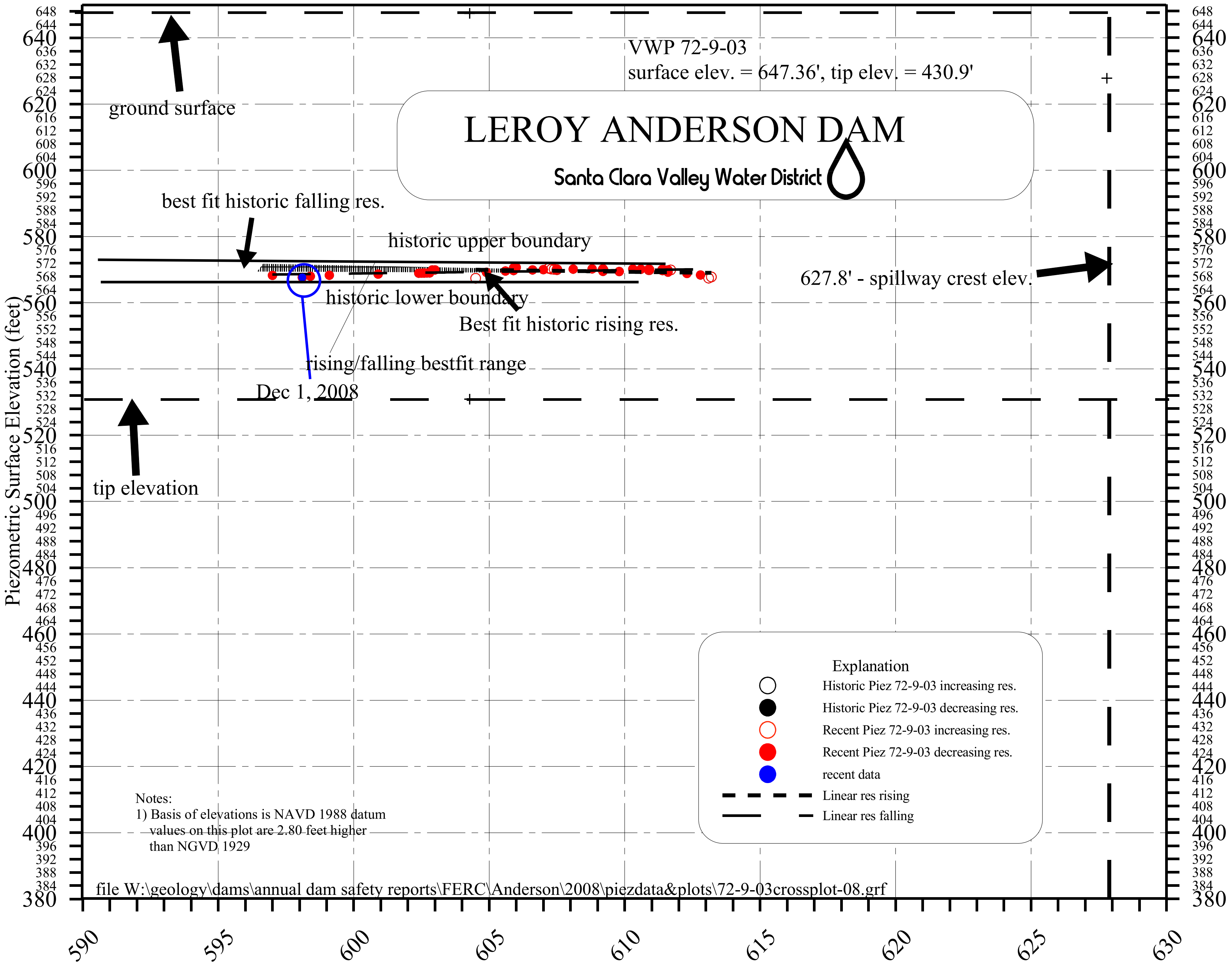
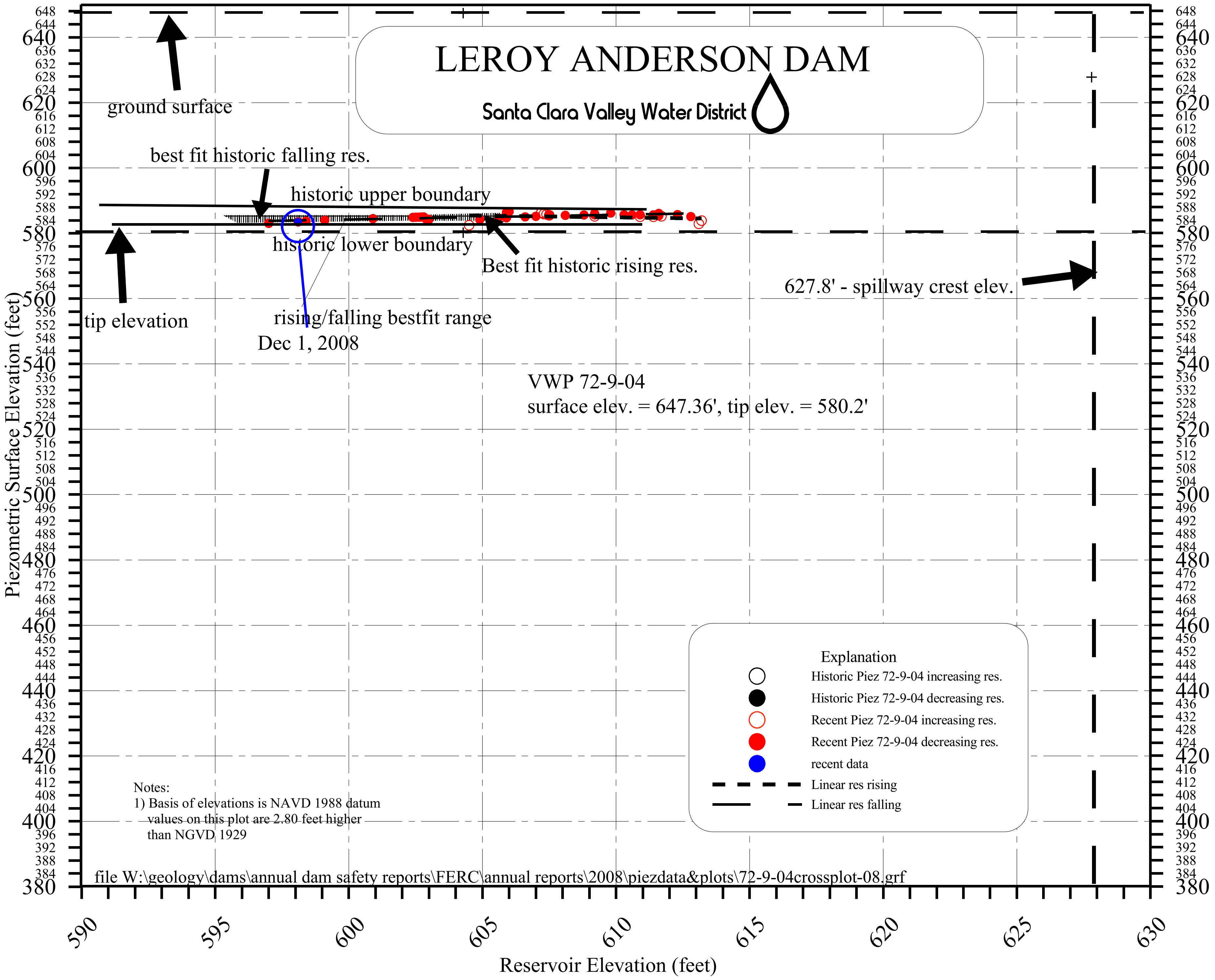


Figure B-3. Cross-Plot of Reservoir Elevation vs. 72-9-03 Piezometer Data



Notes:
1) Basis of elevations is NAVD 1988 datum
values on this plot are 2.80 feet higher
than NGVD 1929

file W:\geology\dams\annual dam safety reports\FERC\annual reports\2008\piezdata&plots\72-9-04crossplot-08.grf

Figure B-4. Cross-Plot of Reservoir Elevation vs. 72-9-04 Piezometer Data

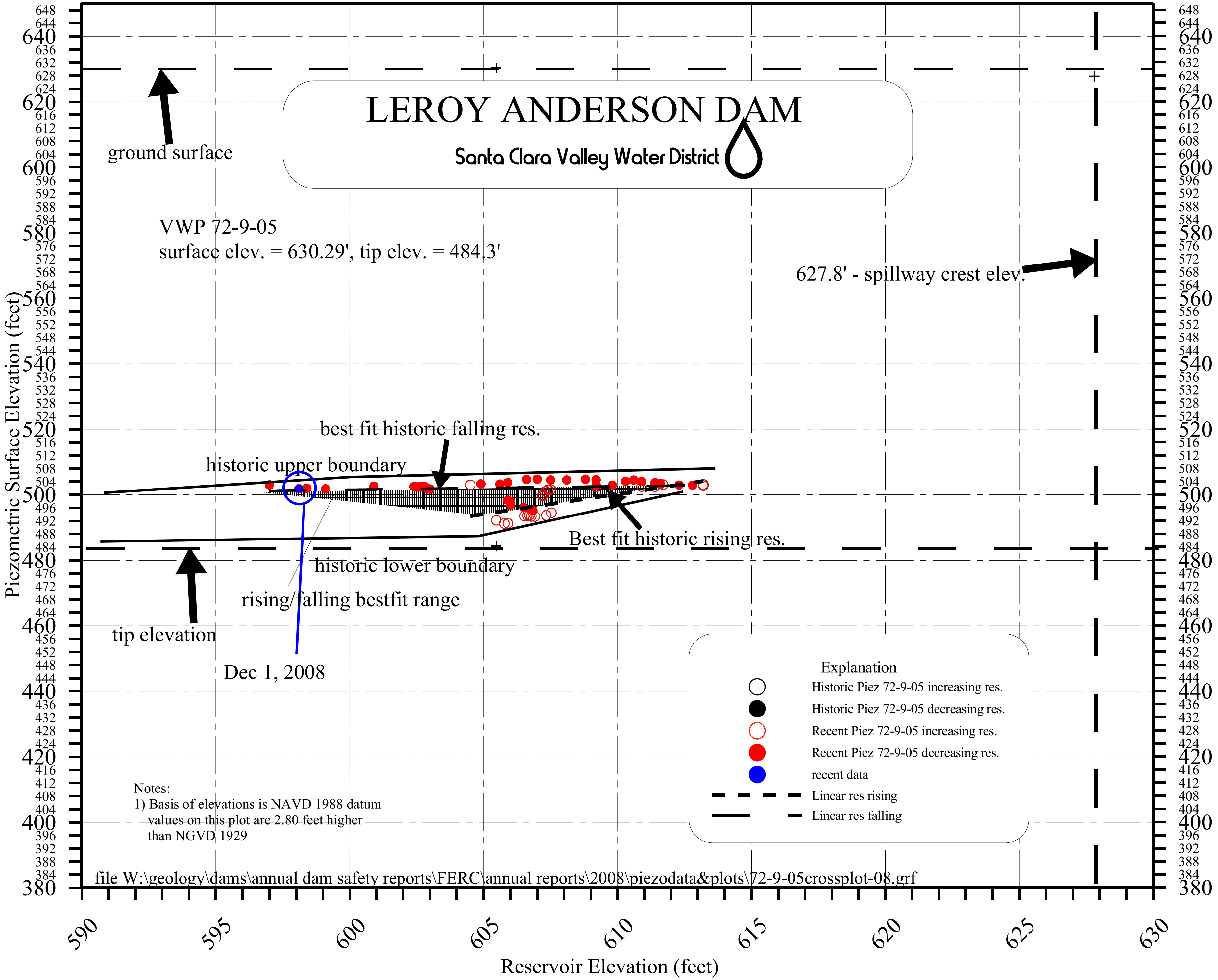


Figure B-5. Cross-Plot of Reservoir Elevation vs. 72-9-05 Piezometer Data

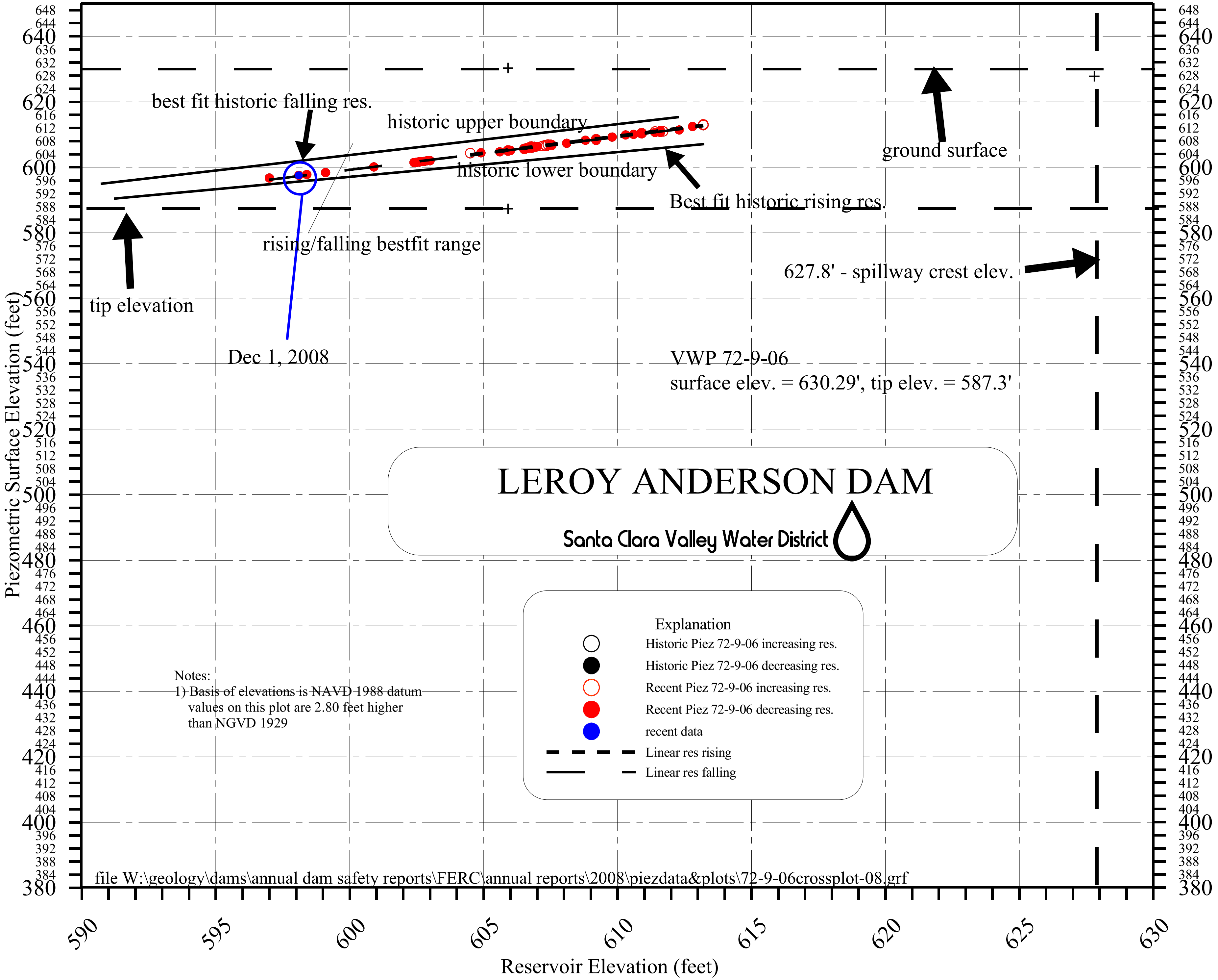


Figure B-6. Cross-Plot of Reservoir Elevation vs. 72-9-06 Piezometer Data

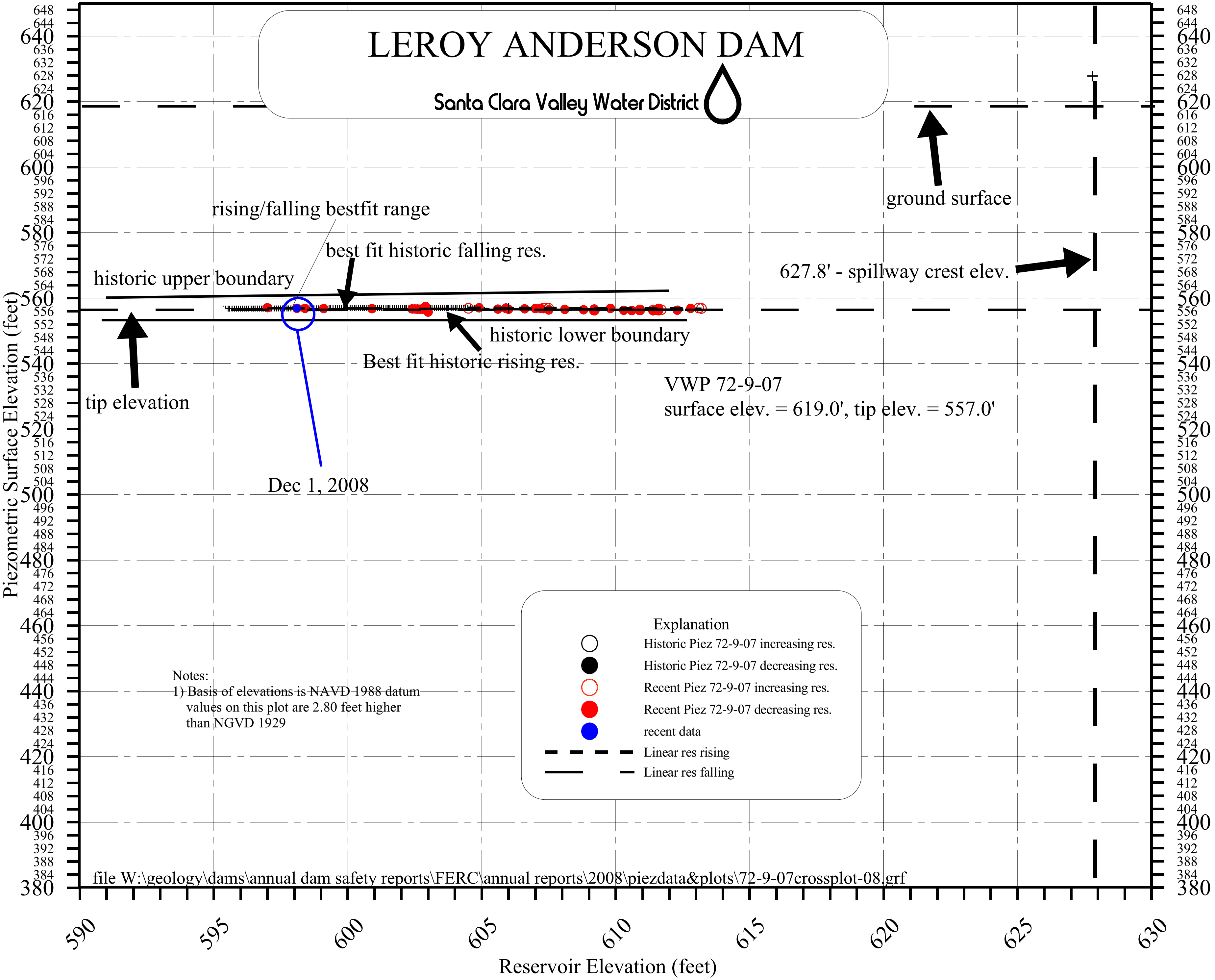


Figure B-7. Cross-Plot of Reservoir Elevation vs. 72-9-07 Piezometer Data

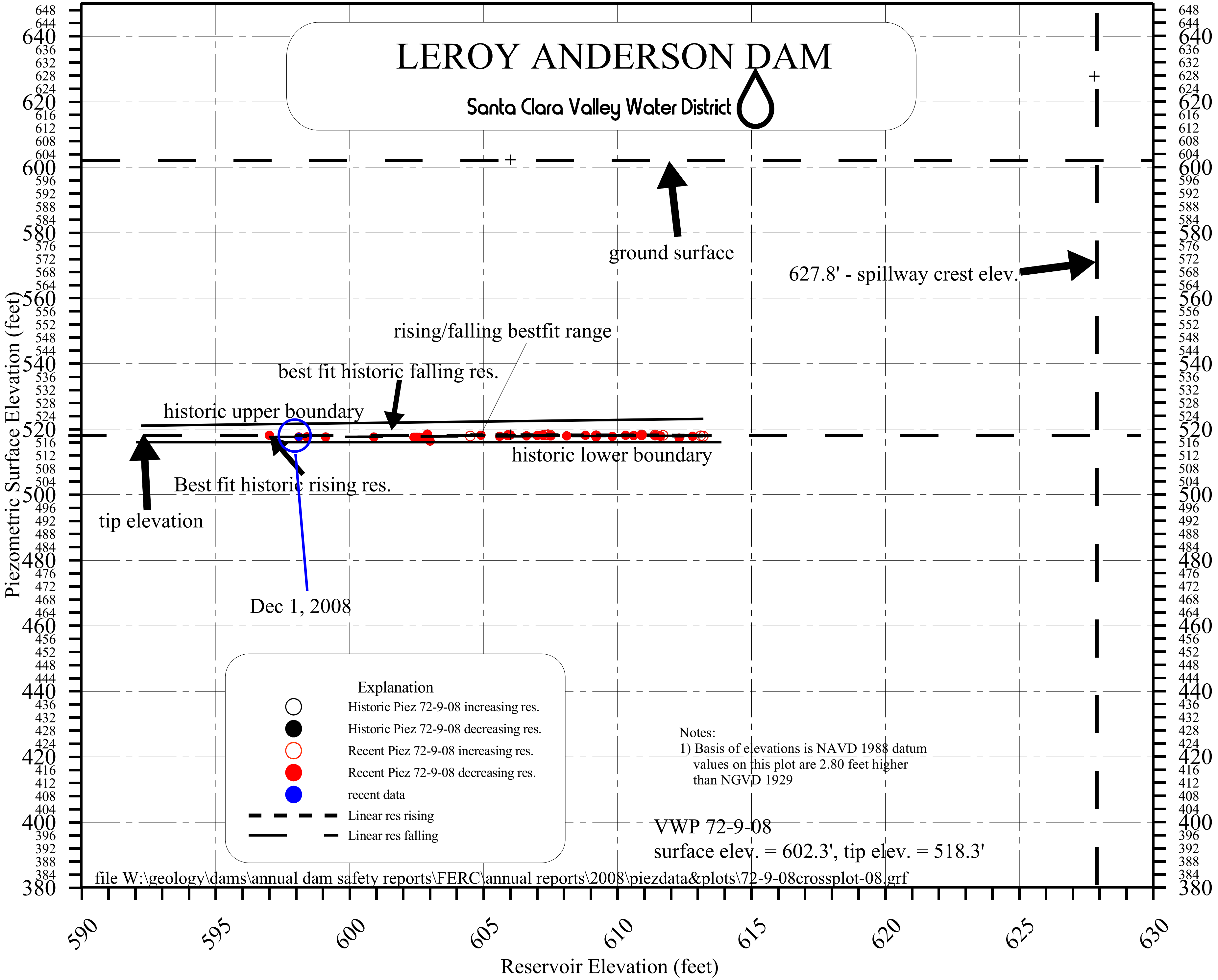


Figure B-8. Cross-Plot of Reservoir Elevation vs. 72-9-08 Piezometer Data

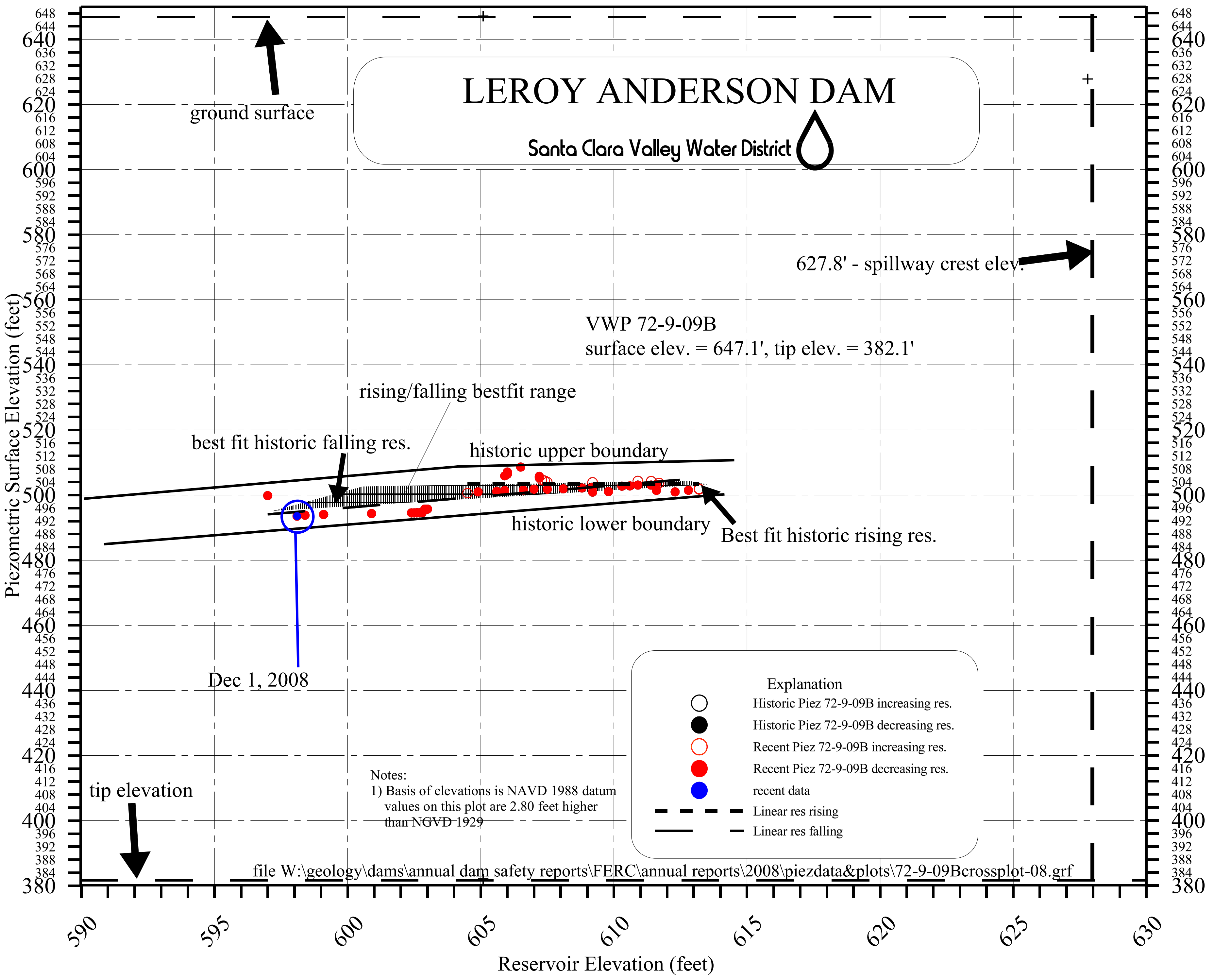


Figure B-9. Cross-Plot of Reservoir Elevation vs. 72-9-09B Piezometer Data

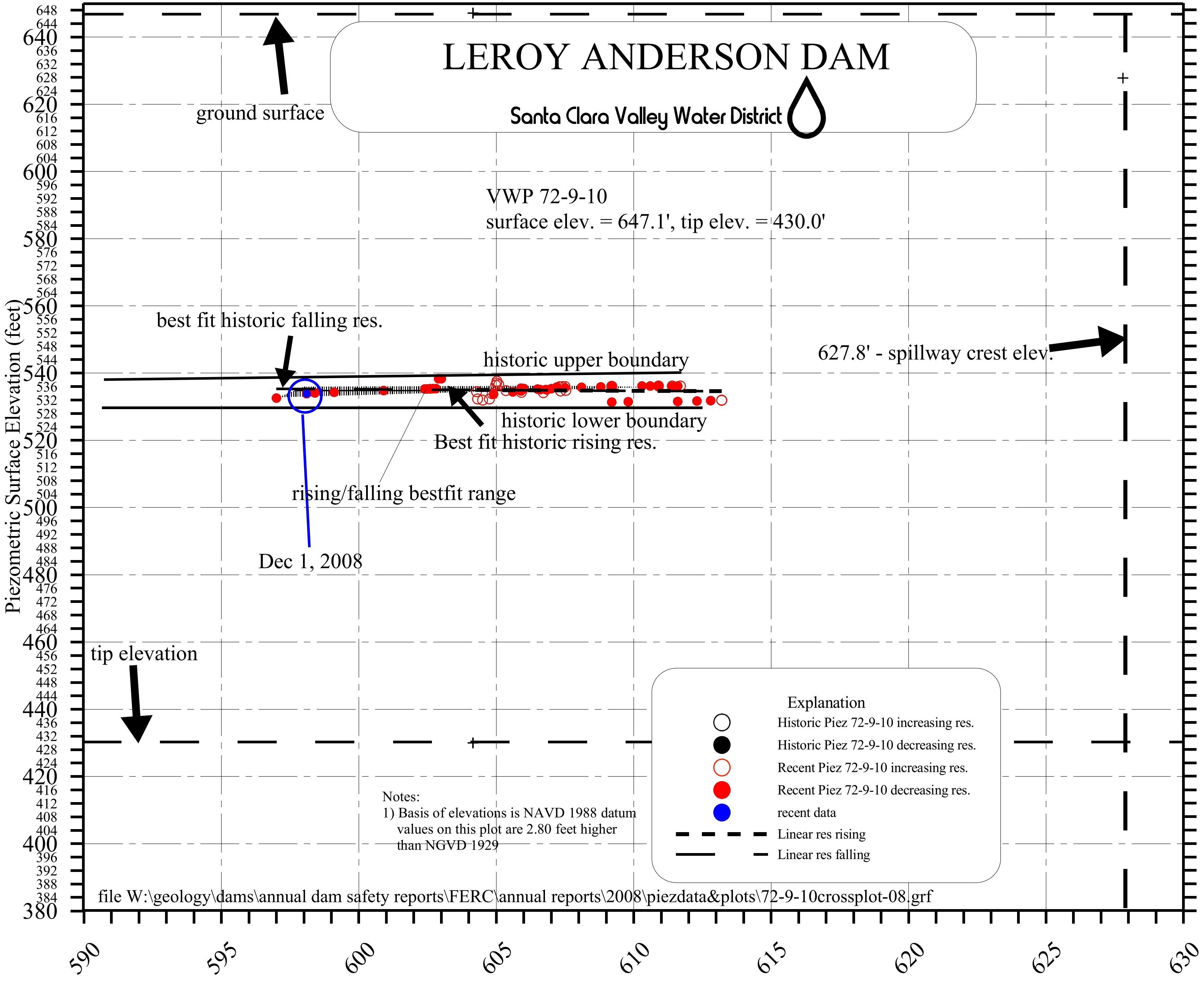
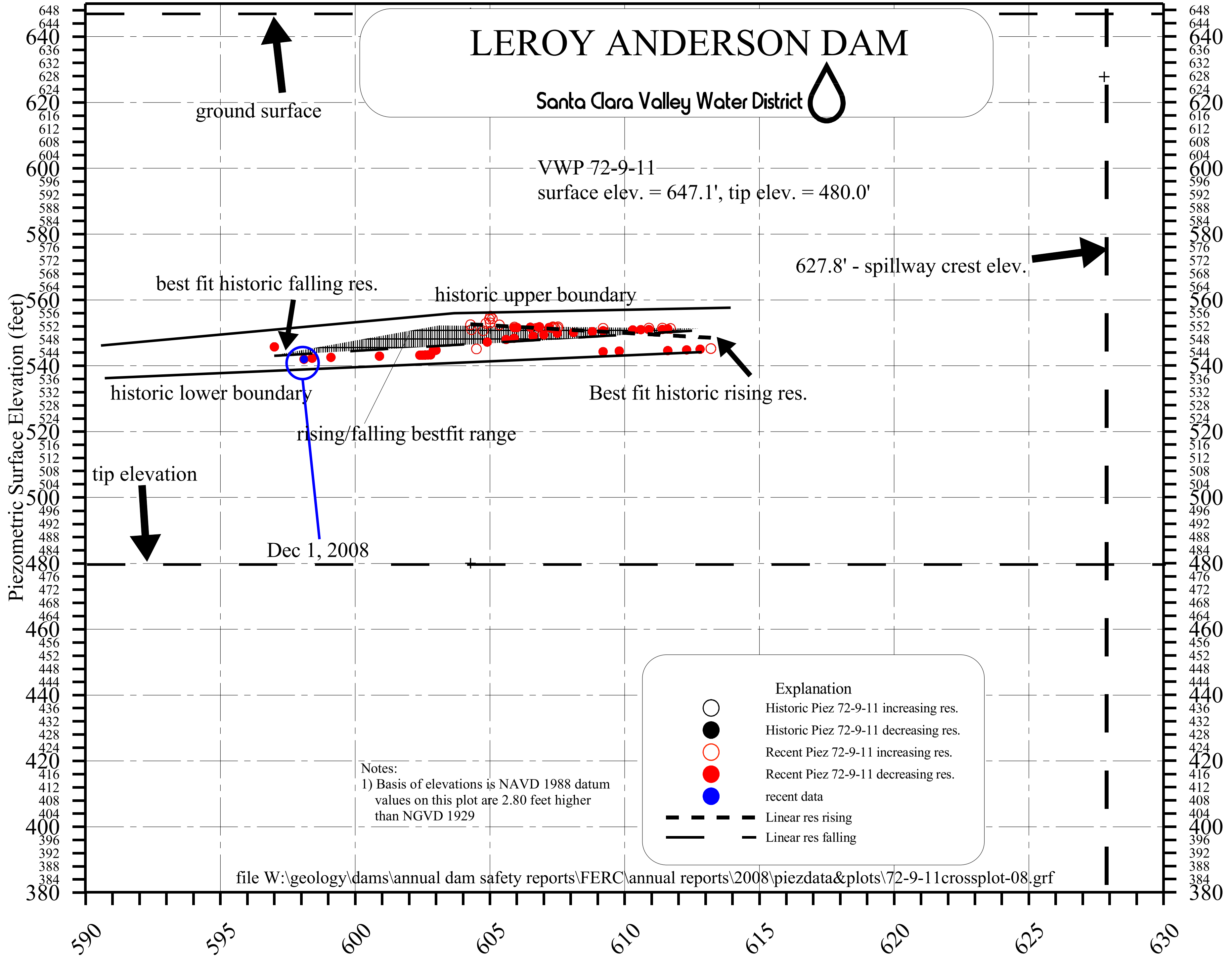


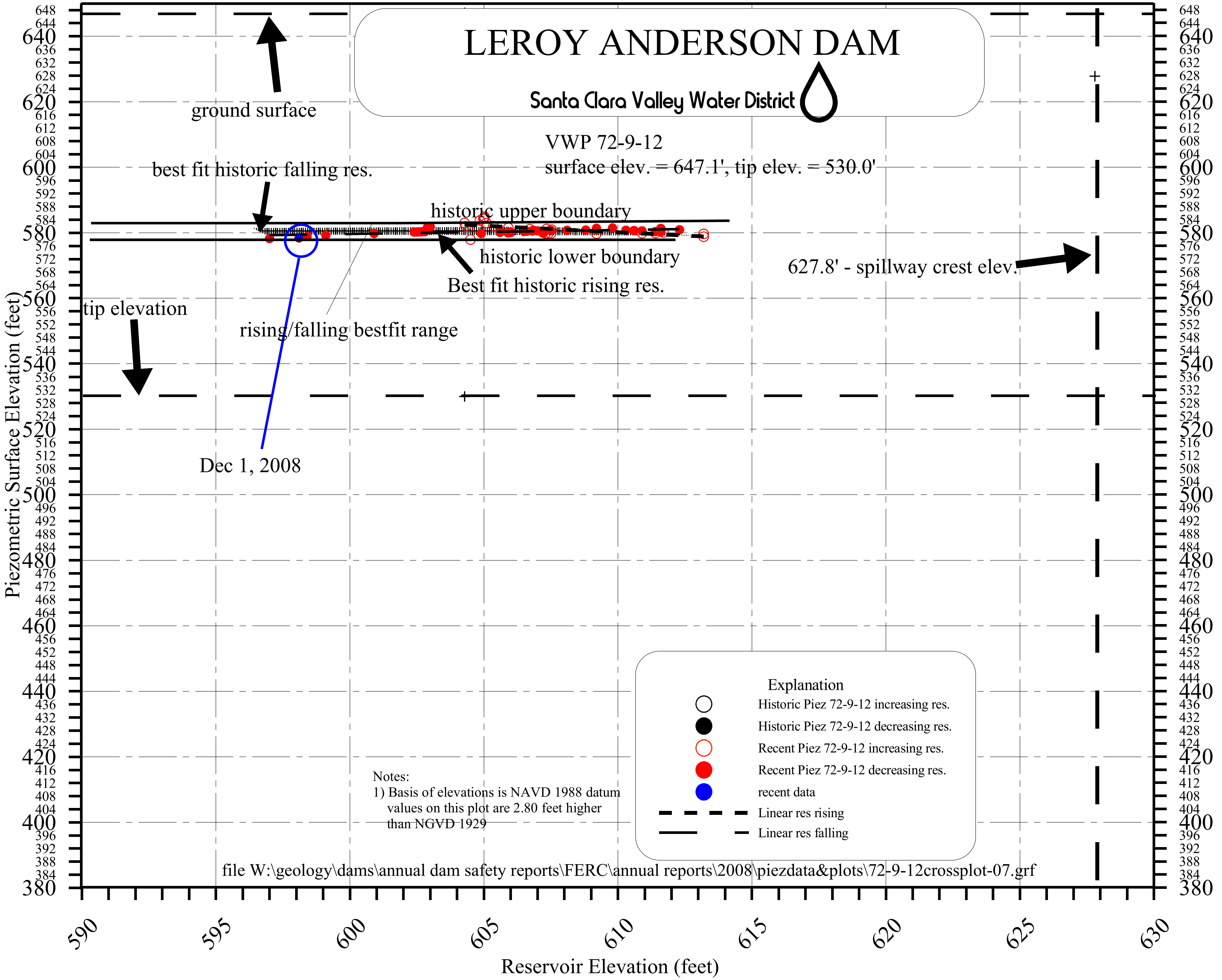
Figure B-10. Cross-Plot of Reservoir Elevation vs. 72-9-10 Piezometer Data



Notes:
1) Basis of elevations is NAVD 1988 datum values on this plot are 2.80 feet higher than NGVD 1929

file W:\geology\dams\annual dam safety reports\FERC\annual reports\2008\piezdata&plots\72-9-11crossplot-08.grf

Figure B-11. Cross-Plot of Reservoir Elevation vs. 72-9-11 Piezometer Data



Notes:
1) Basis of elevations is NAVD 1988 datum values on this plot are 2.80 feet higher than NGVD 1929

file W:\geology\dams\annual dam safety reports\FERC\annual reports\2008\piezdata&plots\72-9-12crossplot-07.grf

Figure B-12. Cross-Plot of Reservoir Elevation vs. 72-9-12 Piezometer Data

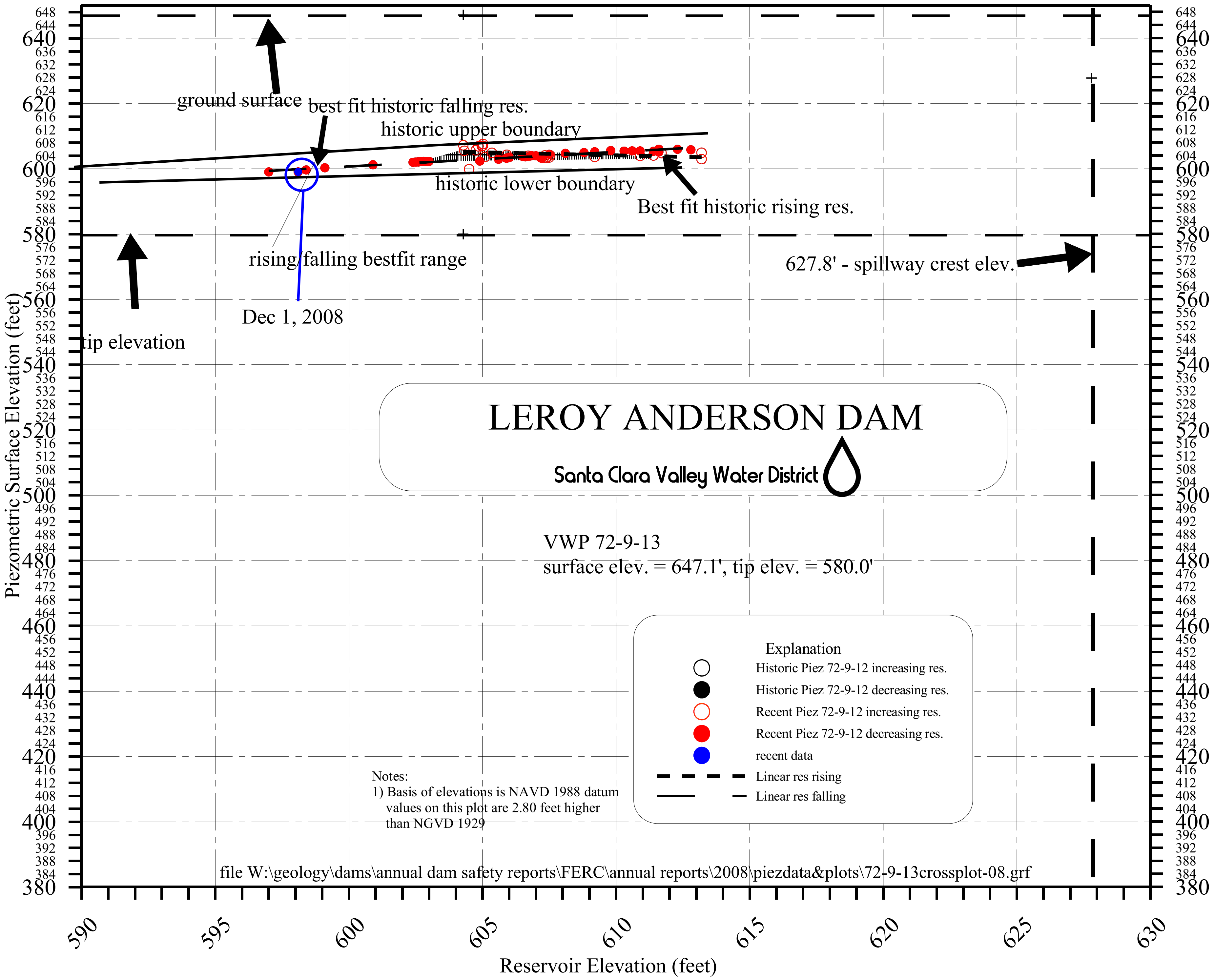


Figure B-13. Cross-Plot of Reservoir Elevation vs. 72-9-13 Piezometer Data

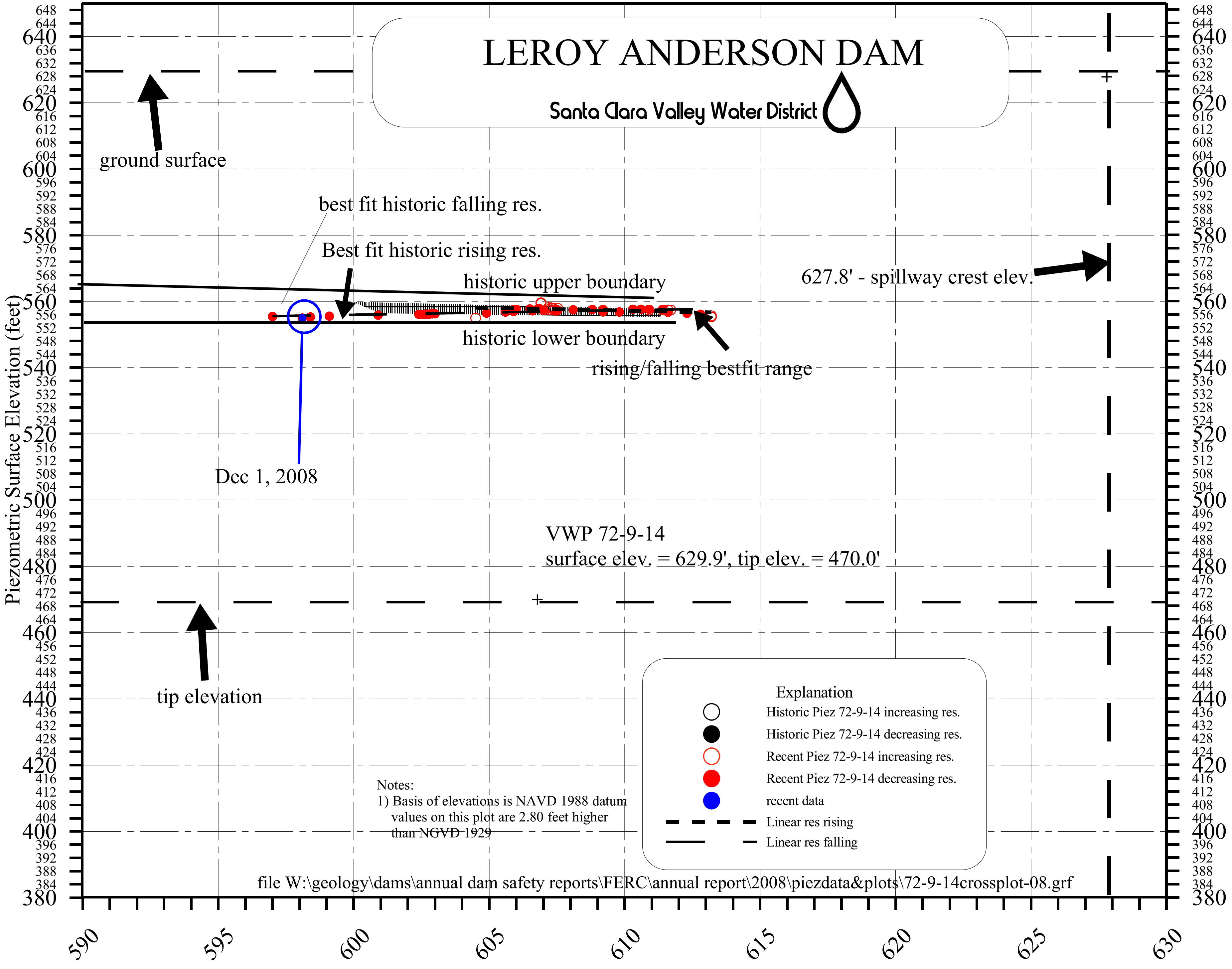


Figure B-14. Cross-Plot of Reservoir Elevation vs. 72-9-14 Piezometer Data

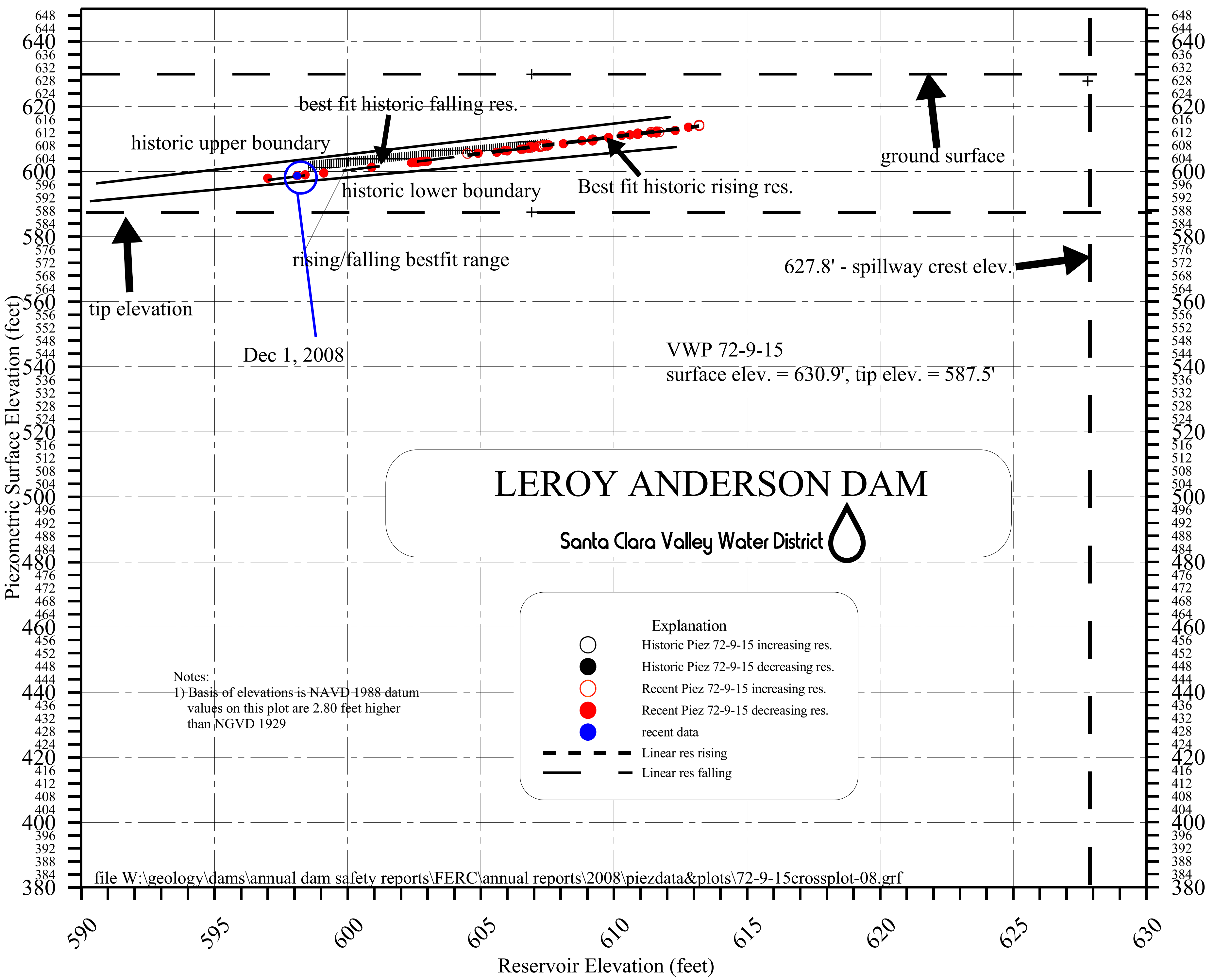


Figure B-15. Cross-Plot of Reservoir Elevation vs. 72-9-15 Piezometer Data

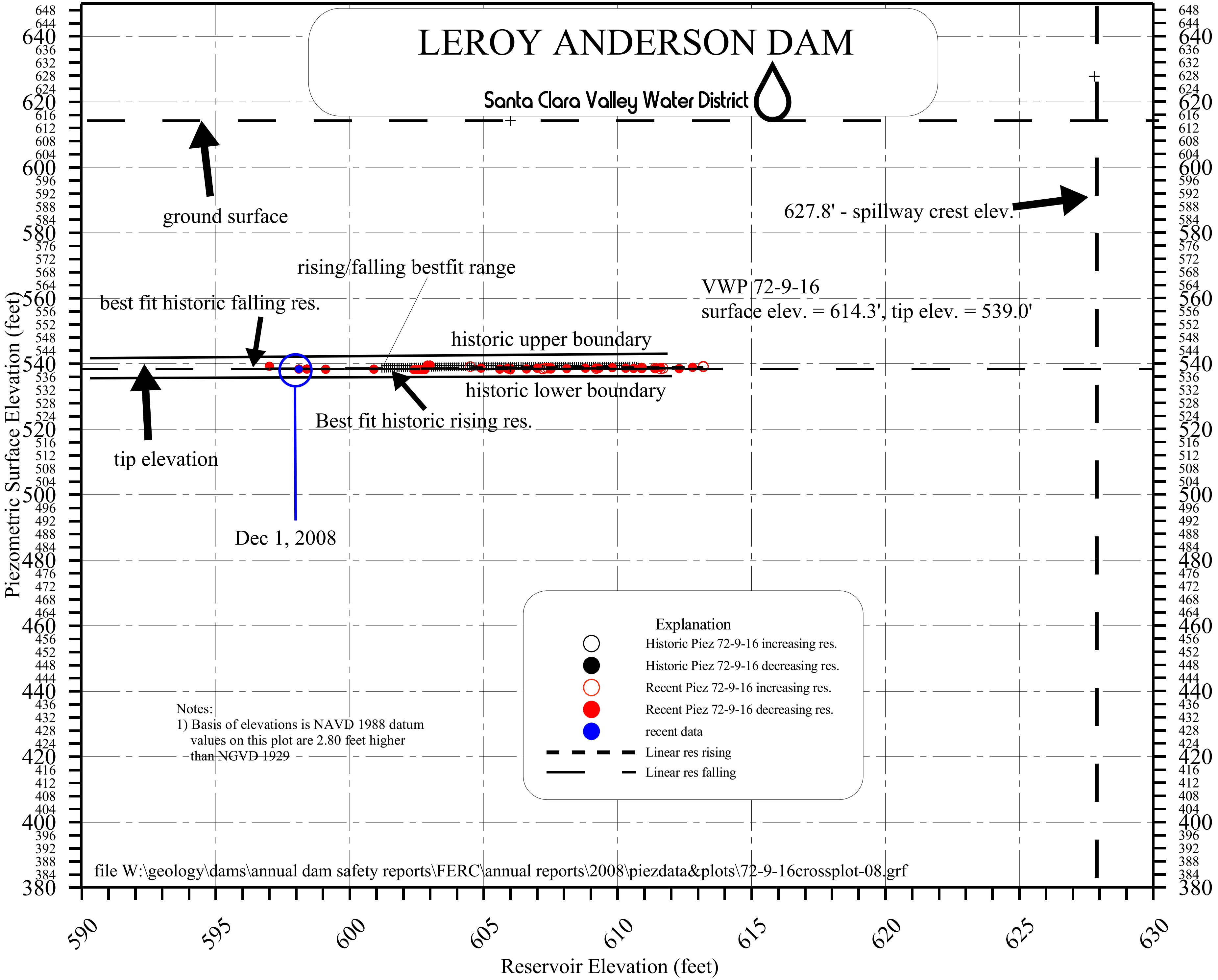


Figure B-16. Cross-Plot of Reservoir Elevation vs. 72-9-16 Piezometer Data

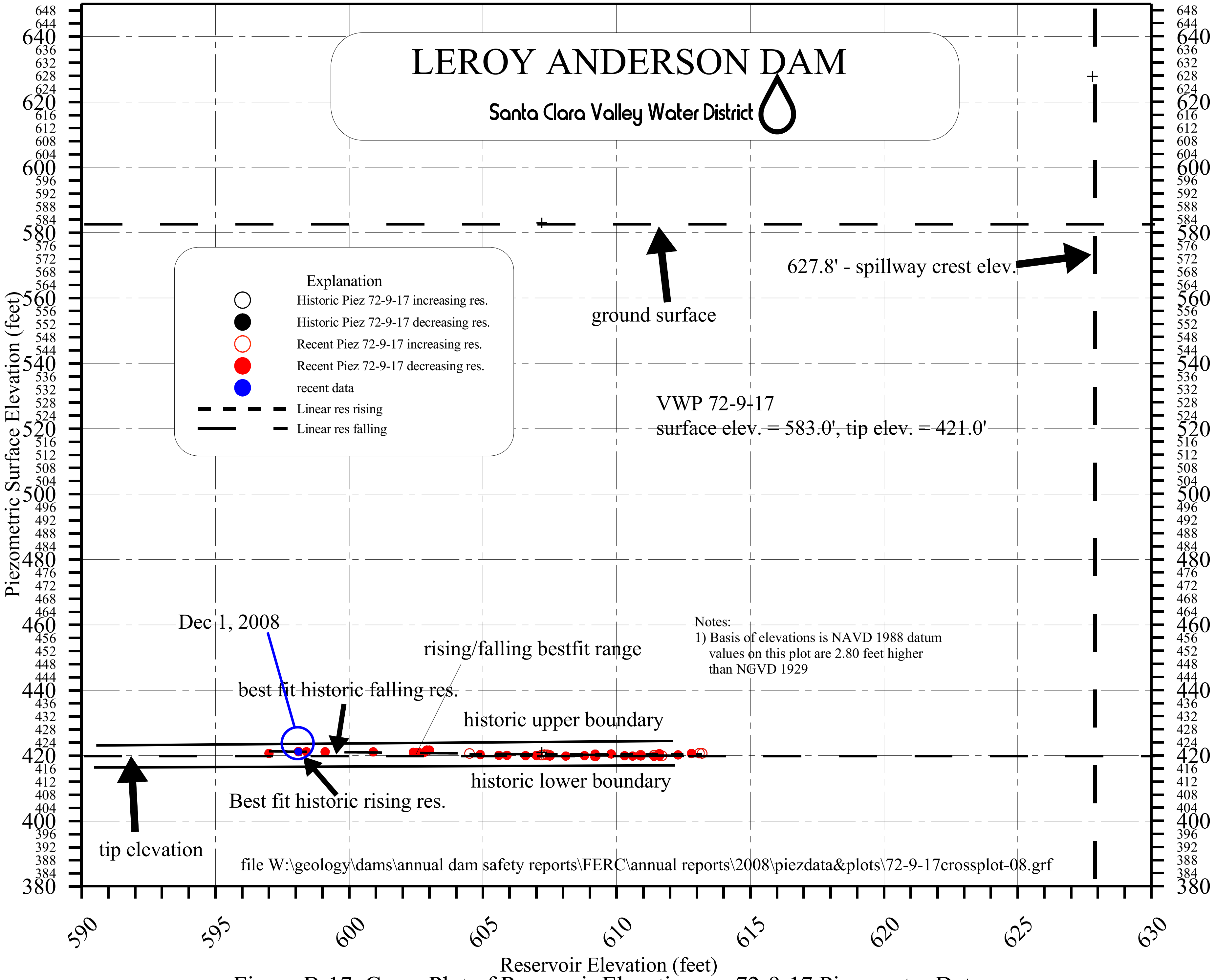


Figure B-17. Cross-Plot of Reservoir Elevation vs. 72-9-17 Piezometer Data

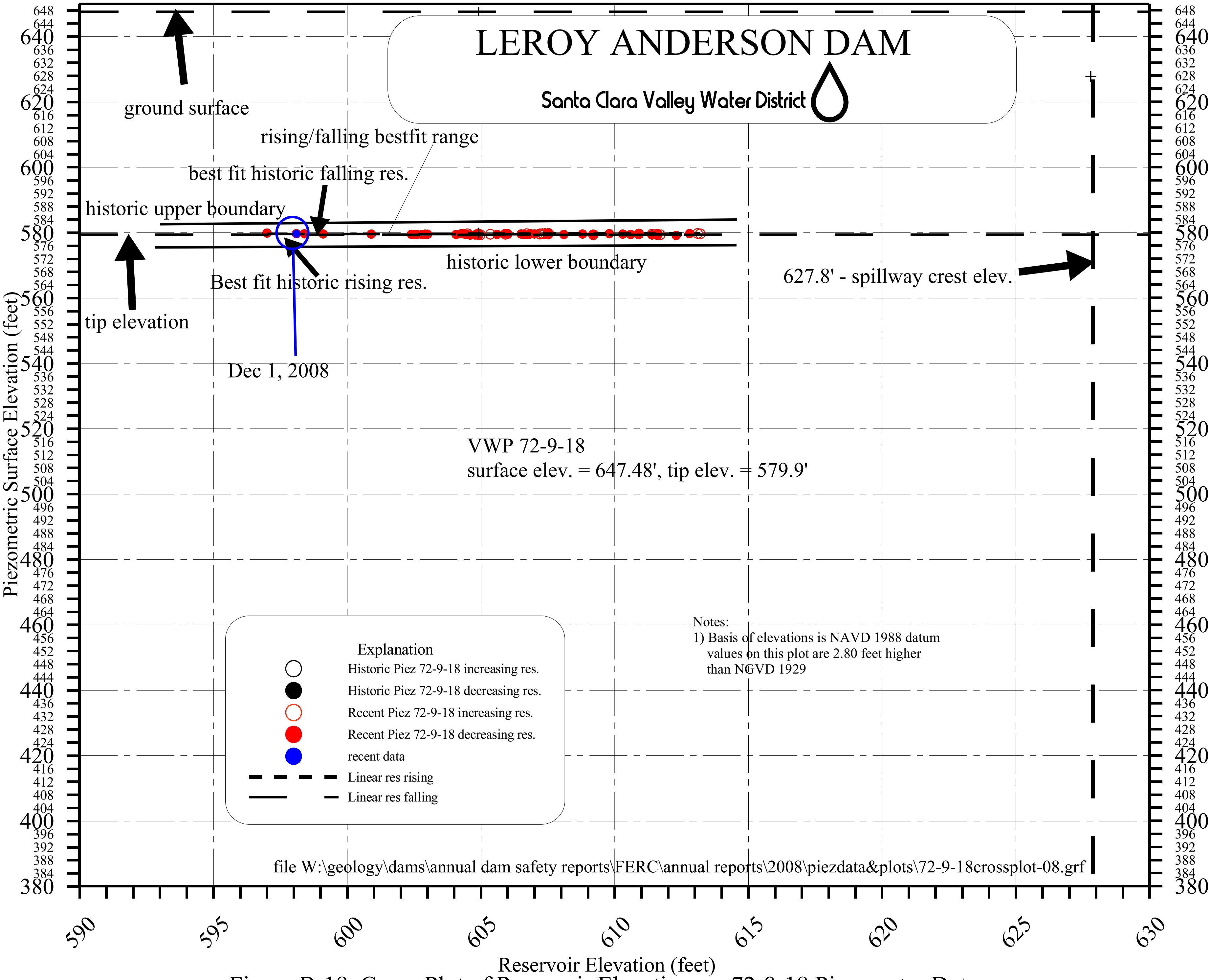


Figure B-18. Cross-Plot of Reservoir Elevation vs. 72-9-18 Piezometer Data

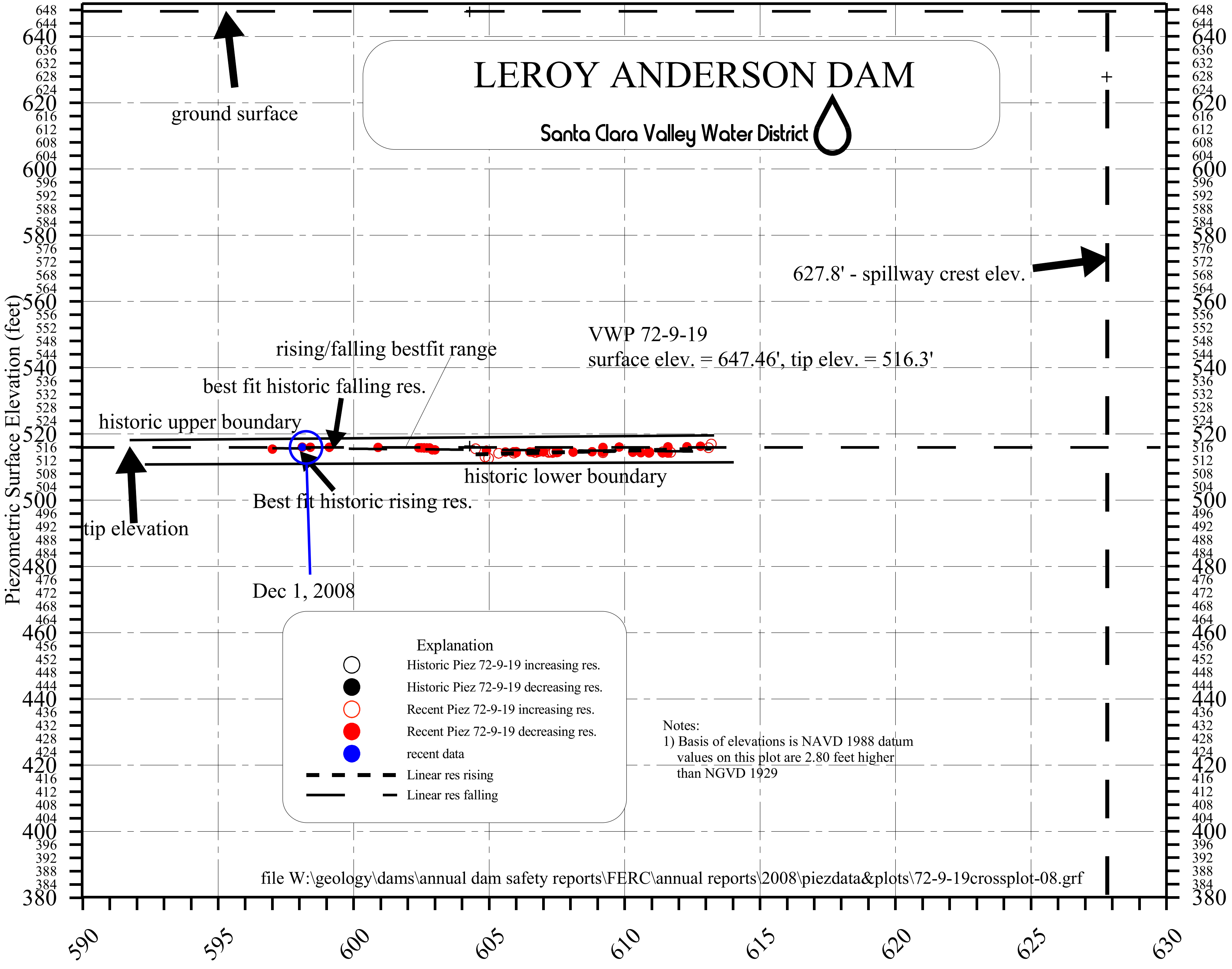


Figure B-19. Cross-Plot of Reservoir Elevation vs. 72-9-19 Piezometer Data

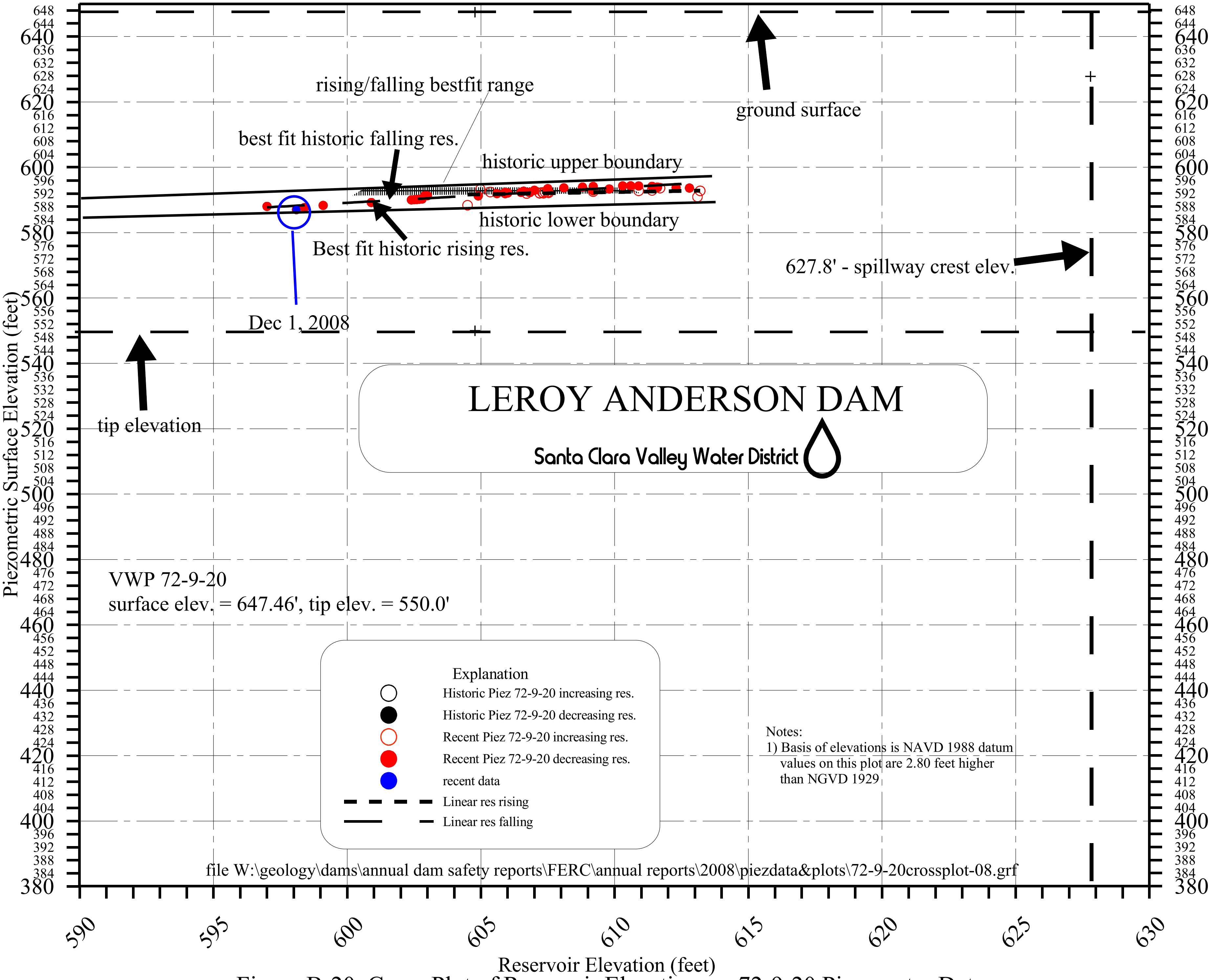


Figure B-20. Cross-Plot of Reservoir Elevation vs. 72-9-20 Piezometer Data

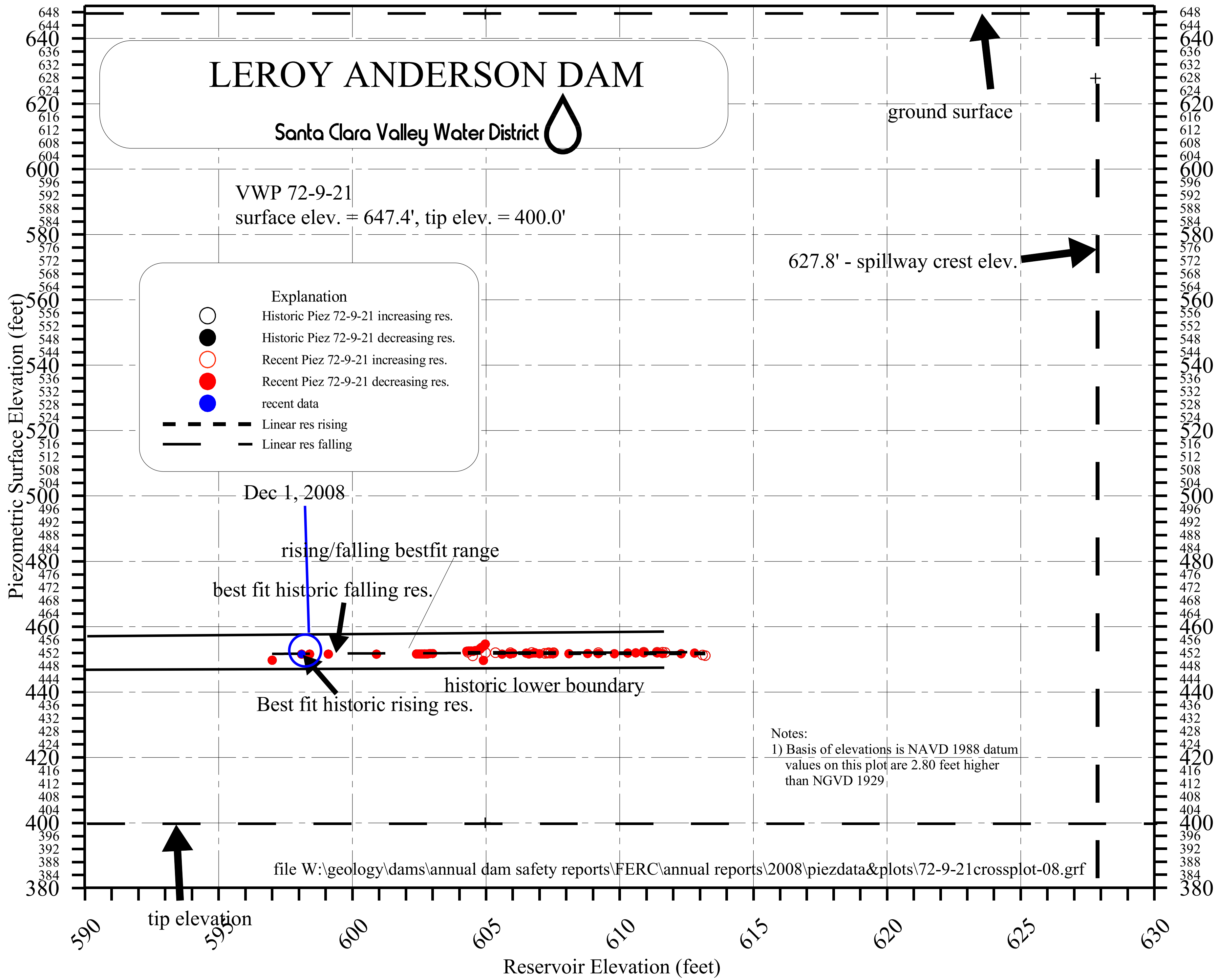


Figure B-21. Cross-Plot of Reservoir Elevation vs. 72-9-21 Piezometer Data

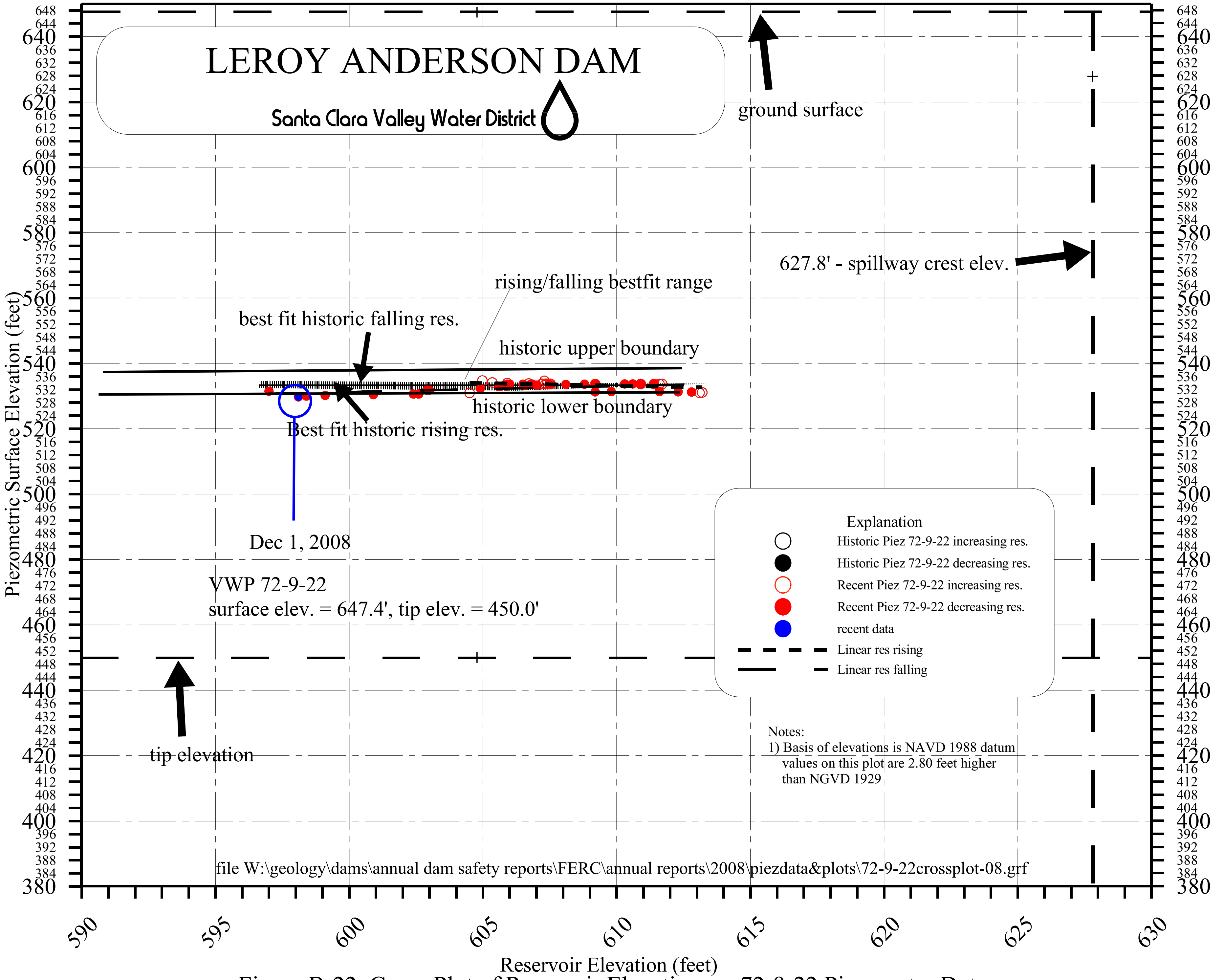
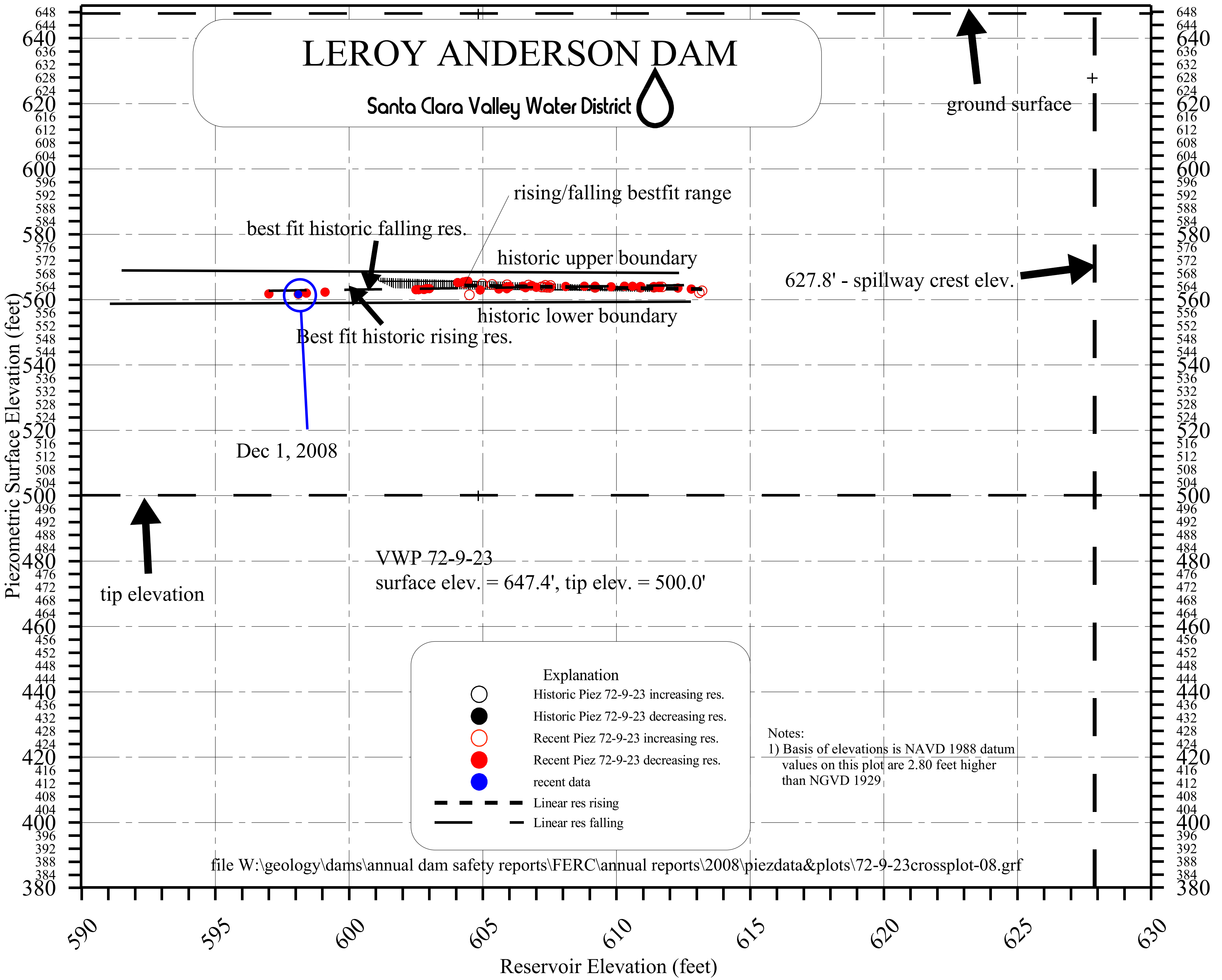


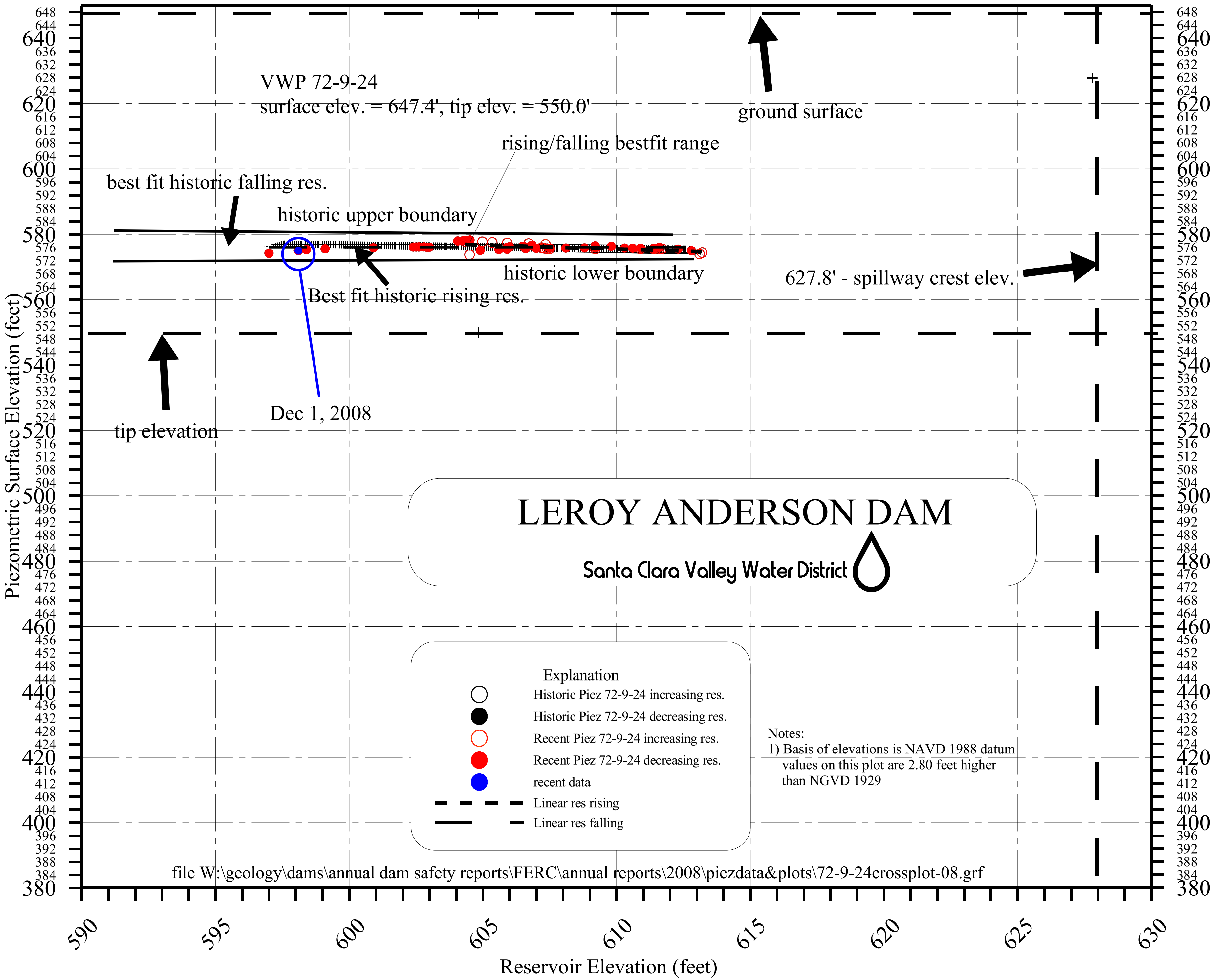
Figure B-22. Cross-Plot of Reservoir Elevation vs. 72-9-22 Piezometer Data



Notes:
1) Basis of elevations is NAVD 1988 datum values on this plot are 2.80 feet higher than NGVD 1929

file W:\geology\dams\annual dam safety reports\FERC\annual reports\2008\piezdata&plots\72-9-23crossplot-08.grf

Figure B-23. Cross-Plot of Reservoir Elevation vs. 72-9-23 Piezometer Data



Notes:
1) Basis of elevations is NAVD 1988 datum values on this plot are 2.80 feet higher than NGVD 1929

Figure B-24. Cross-Plot of Reservoir Elevation vs. 72-9-24 Piezometer Data

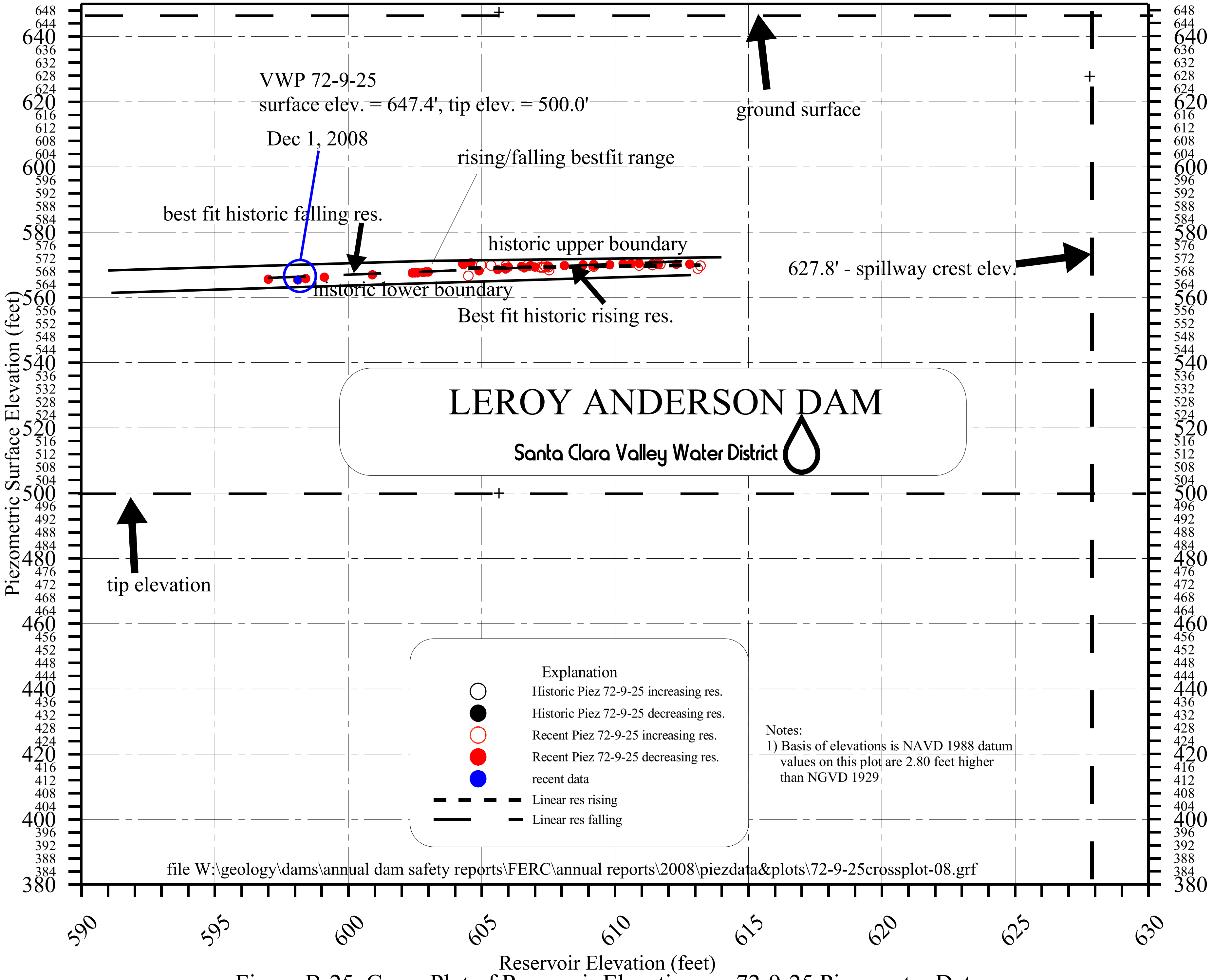


Figure B-25. Cross-Plot of Reservoir Elevation vs. 72-9-25 Piezometer Data

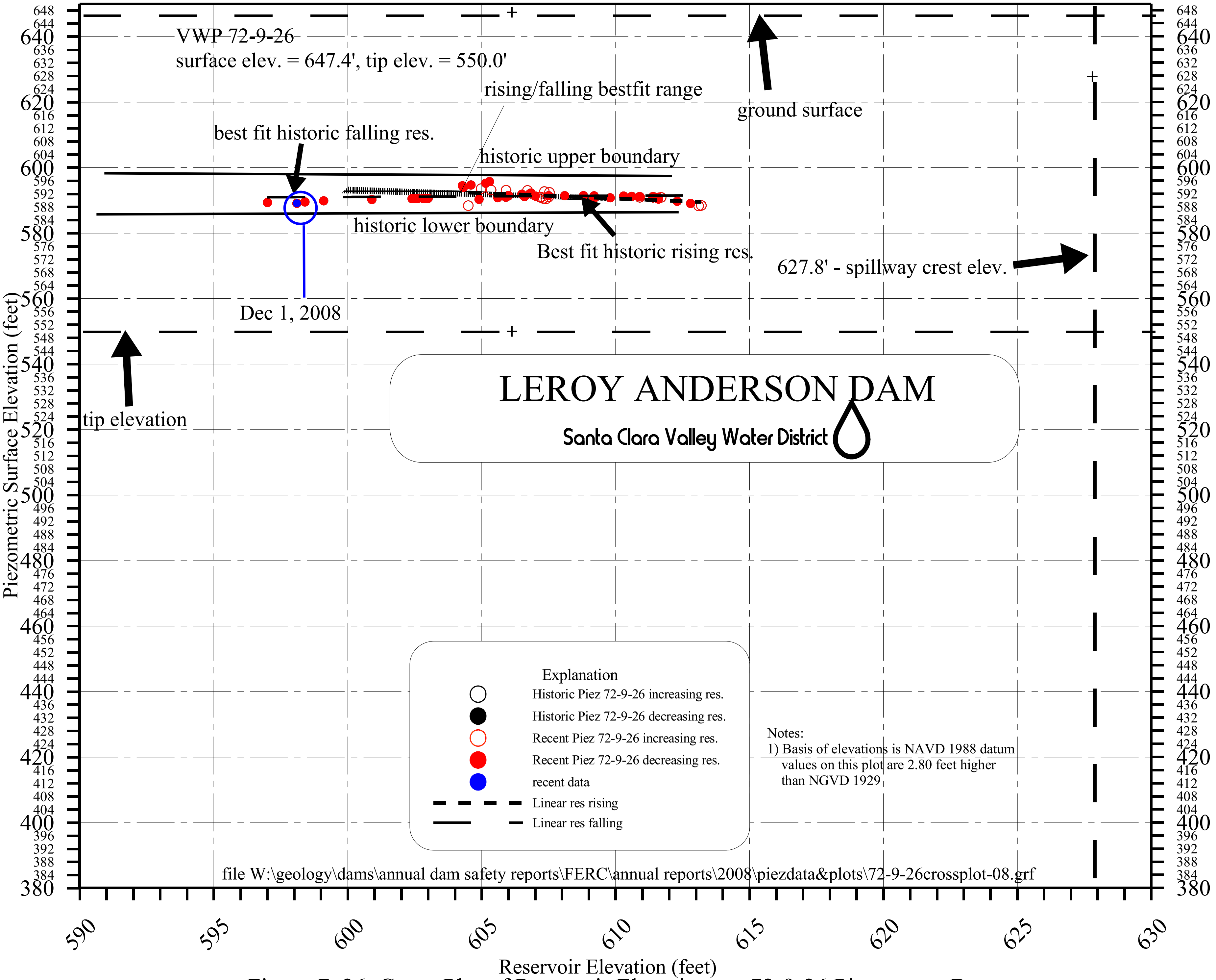


Figure B-26. Cross-Plot of Reservoir Elevation vs. 72-9-26 Piezometer Data

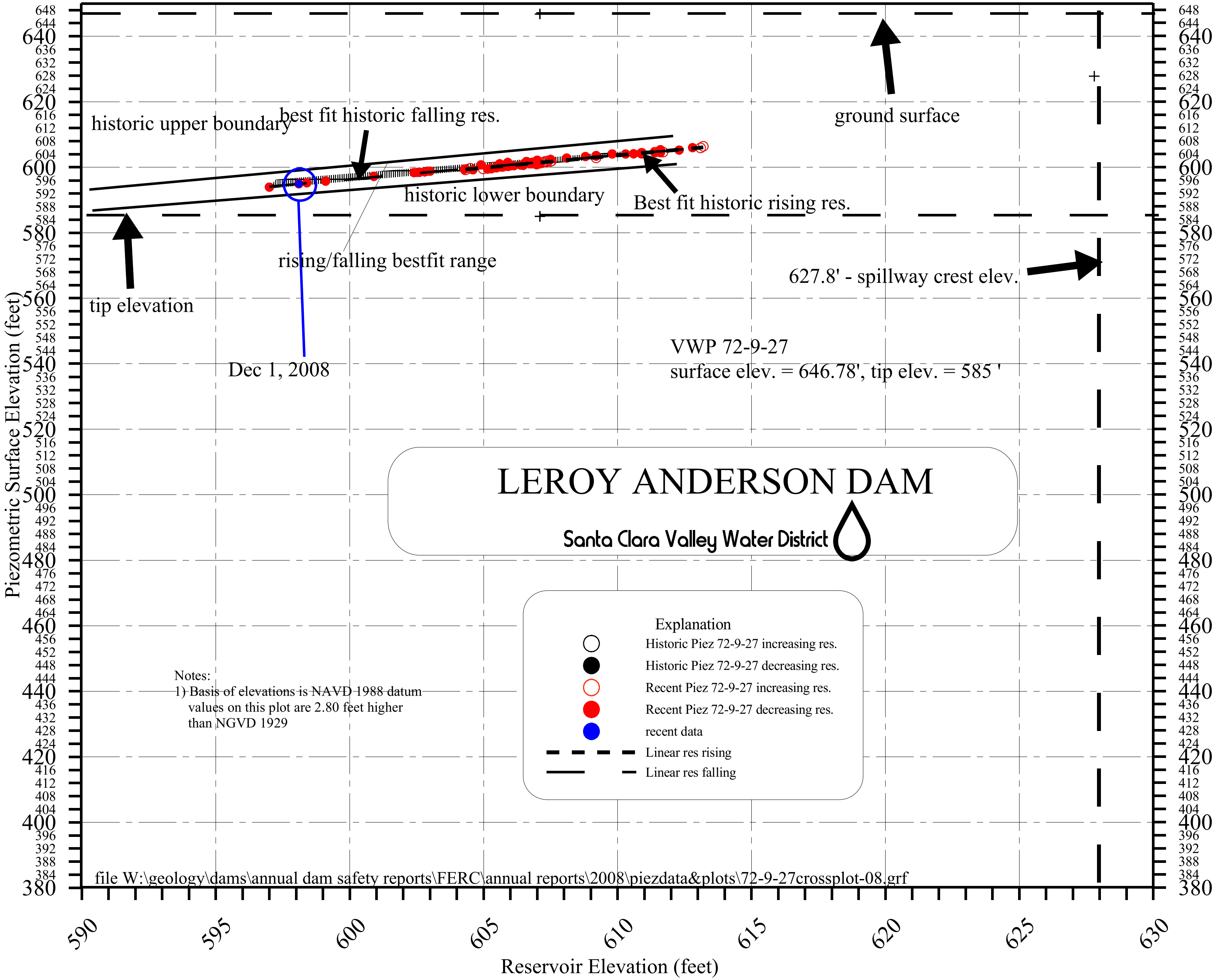


Figure B-27. Cross-Plot of Reservoir Elevation vs. 72-9-27 Piezometer Data

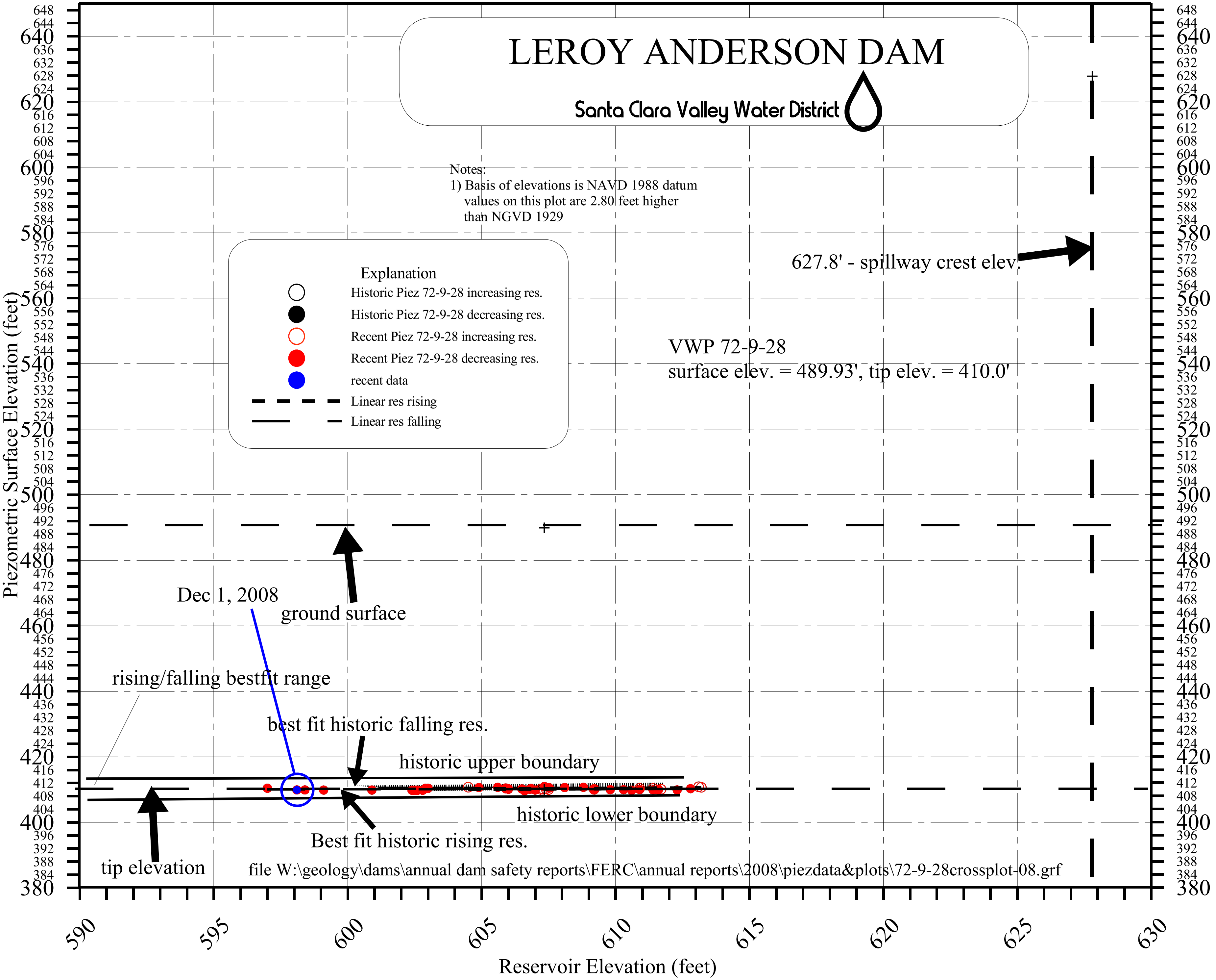


Figure B-28. Cross-Plot of Reservoir Elevation vs. 72-9-28 Piezometer Data

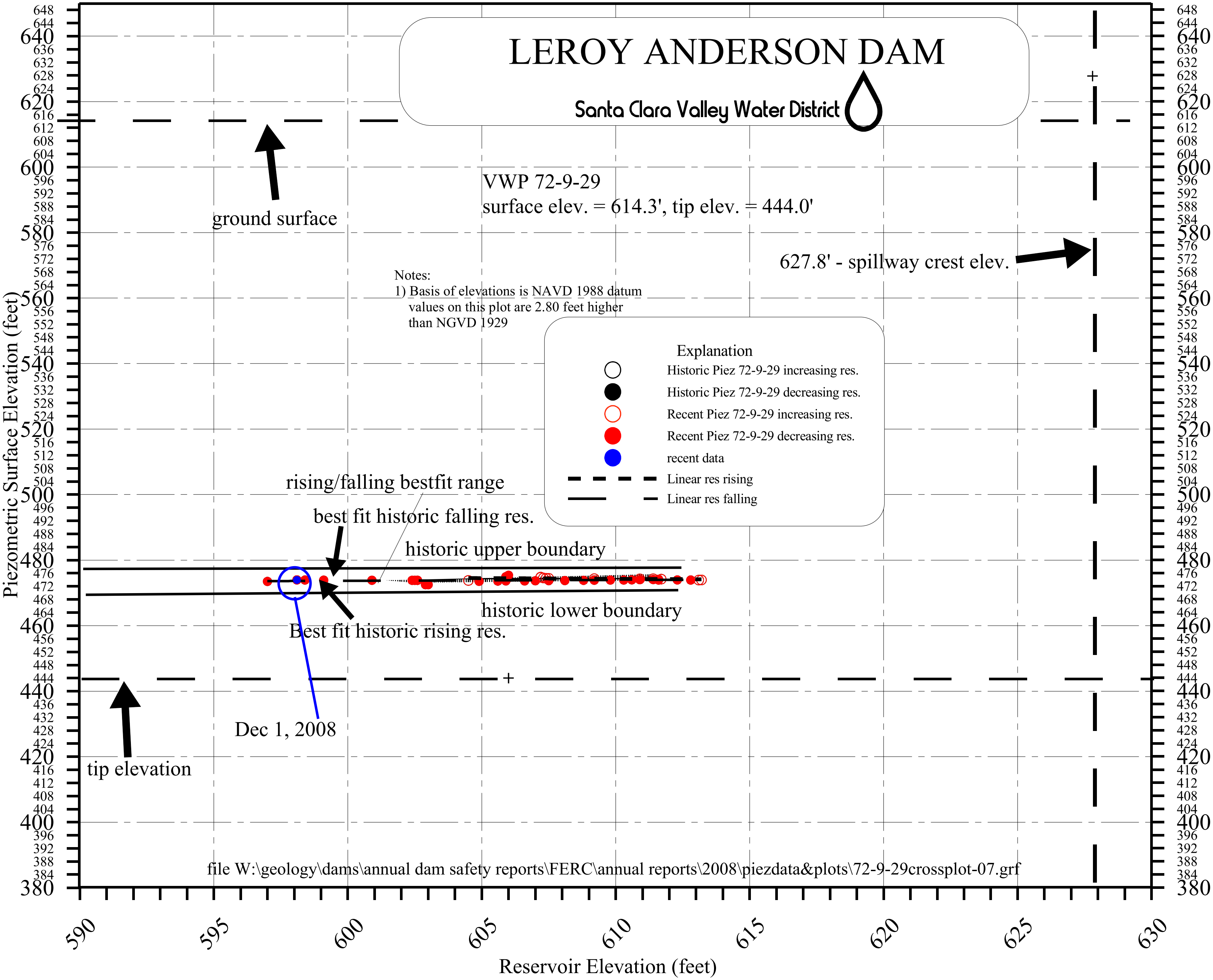


Figure B-29. Cross-Plot of Reservoir Elevation vs. 72-9-29 Piezometer Data

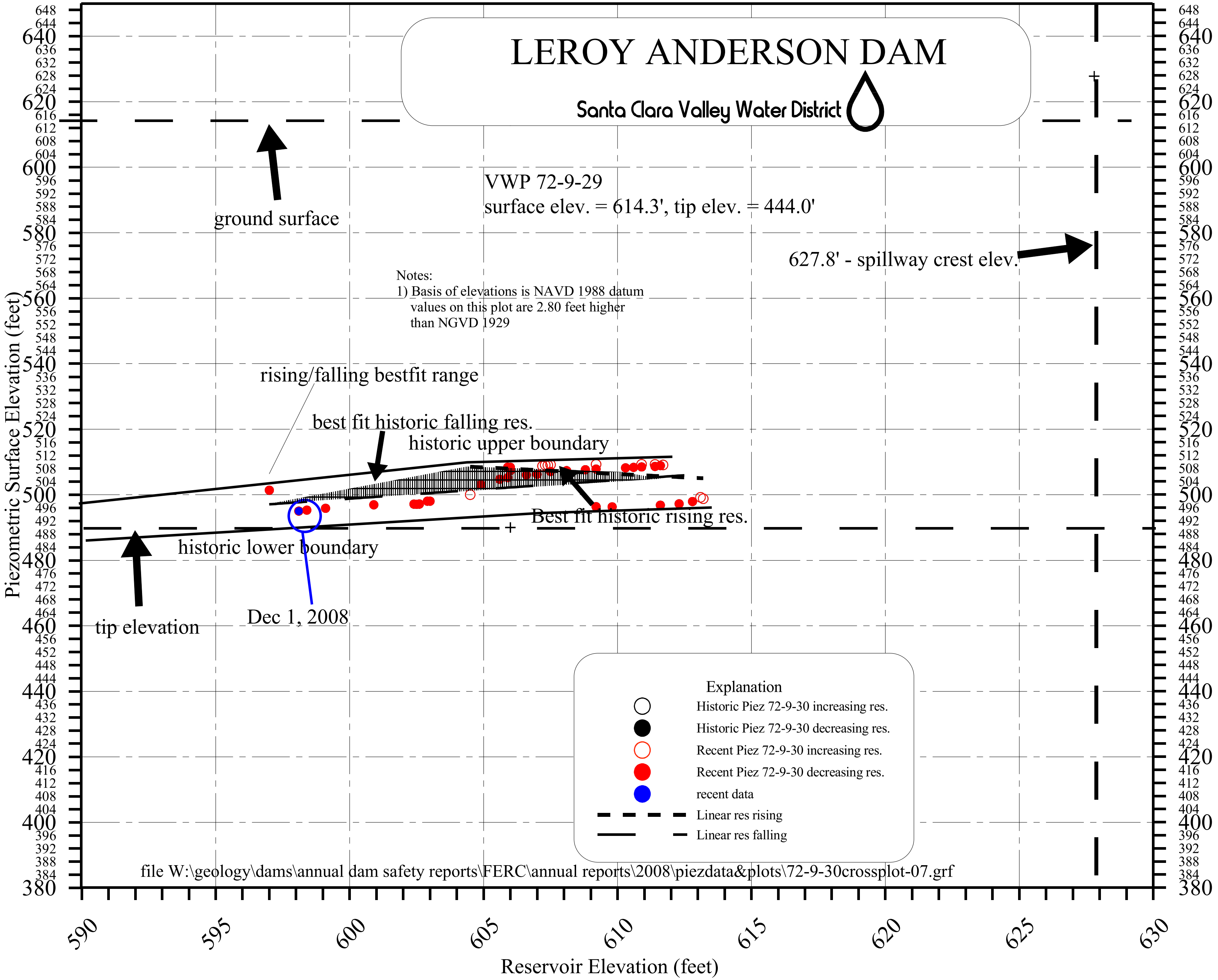


Figure B-30. Cross-Plot of Reservoir Elevation vs. 72-9-30 Piezometer Data

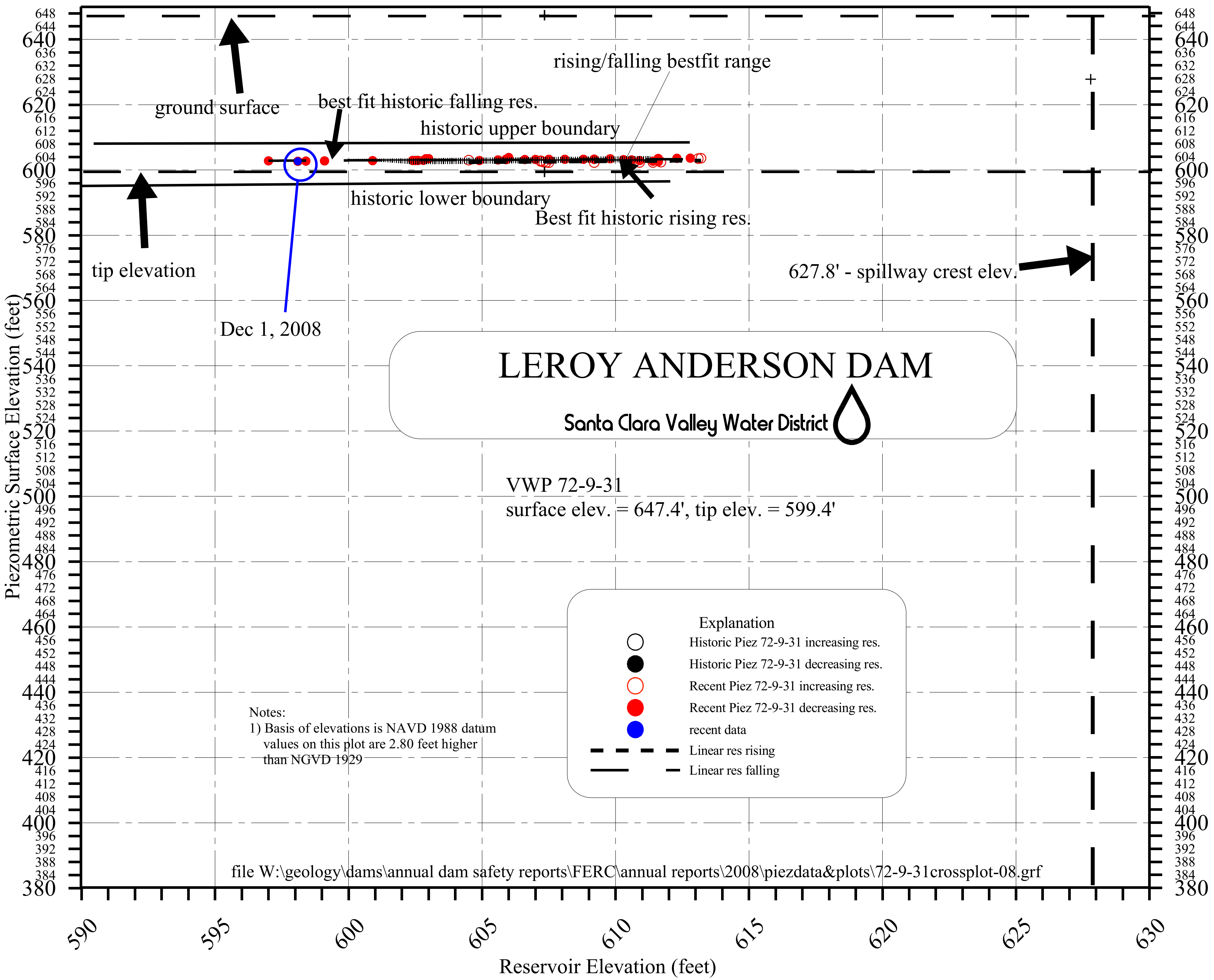


Figure B-31. Cross-Plot of Reservoir Elevation vs. 72-9-31 Piezometer Data

Appendix C – November 4, 2008 Memo on Geologic Observations During Repair of Boat Ramp Landslide

J. Nelson Memorandum to Y. Arroyo dated November 4, 2008: *Observations of Additional Landslides During Repair of the Boat Ramp Landslide, Anderson Dam & Reservoir*

Santa Clara Valley Water District

MEMORANDUM

TO: Yvonne Arroyo
Associate Engineering
Community Projects Review Unit

FROM James L. Nelson
Senior Engineering Geologist
Dam Safety Program Unit

SUBJECT Observations of Additional Landslides During Repair of the Boat Ramp Landslide, Anderson Dam & Reservoir

DATE: November 4, 2008

cc: S. Tippets, D. Hook, R.L. Volpe, B. Baker, D. Zozaya, J. Nelson

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1.0 INTRODUCTION

The main objective of this memorandum is to make the District aware that additional landslide shear surfaces were exposed during recent repair of a landslide located on the upslope side of the boat ramp at Leroy Anderson Dam and Reservoir (hereafter termed “the Boat Ramp Landslide”). The Boat Ramp Landslide is situated upstream of the left (south) abutment of Anderson Dam. As discussed below, the additional landslide features were not addressed by the County. A secondary objective of this memo is to document previous and current observations pertinent to the Boat Ramp Landslide.

Widening and upgrades to the previous boat ramp were completed by Santa Clara County Parks and Recreation by late 2003 to early 2004 under a permit issued by the District. During an annual inspection with the Federal Energy Regulatory Commission (FERC) on July 8, 2003, District and FERC personnel observed some cracking of the hillside directly upslope of the boat ramp. Mapping by J. Nelson on July 15, 2003 indicated that grading of the slope adjacent to the boat ramp had been performed by the County as a result of the boat ramp widening. The Boat Ramp Landslide was first noticed approximately 1 year later during the annual FERC inspection of July 2004. The writer mapped the landslide on July 18, 2004 and concluded that the landslide likely involved failure of a fill slope added during boat ramp construction in an email dated July 20, 2004. The County completed their first repair of the Boat Ramp Landslide by November 2004. A second reactivation of the Boat Ramp landslide was noticed by fall 2006, which is the focus of the most recent repair work. According to the geotechnical report for the project prepared by Pacific Geotechnical Engineering (2007) of Morgan Hill, California: “*The recent landslide measures up to approximately 75 feet wide and up to approximately 115 feet from top to bottom and has an uneven slope due to slump of the slid material. The slope gradient before the failure was constructed at a 2:1 (horizontal to vertical) slope.*”

During completion of the current landslide repair, on September 25, 2008, the writer and Assistant Engineering Geologist B. Baker of the Dam Safety Program Unit observed landslide shear surfaces in a keyway trench wall near the upslope head of the Boat Ramp Landslide. The landslide shear surfaces appeared to be basal shear surfaces of individual coalescing landslides, which appear to override the upper portion of the active Boat Ramp Landslide. The current landslide repair effort exposed additional landslide shear surfaces higher in the slope than the Boat Ramp Landslide. Consequently, it was decided in the field on September 25th that the District geologists would record geologic observations of the secondary landslide shears. Once geologic observations were made it was decided by the County that repair of the Boat Ramp Landslide would then be completed without additional work to address the new landslide features. The justification for this decision was that it was not within the original scope of the contract for the contractor (Duran and Venables) to remove and repair landslide areas other than the Boat Ramp Landslide. It was not in the scope of our inspections to map in detail the extent of the coalescing landslides.

Based on the above discussion, there is a remote possibility that future landsliding could occur in the vicinity of the Boat Ramp Landslide due to movement on the secondary coalescing landslides. They are considered coalescing landslides because the southwestern limb of one landslide and the northeastern limb of the other landslide appear to be draped over one another. The following paragraphs discuss the significance of the secondary landslides that appear to be related to landslides mapped by former District Engineering Geologist Jim Scott in 1977.

Any future slope instability in the vicinity of the Boat Ramp Landslide will not likely affect the dam itself; however, a reactivated landslide has the potential to adversely affect the District's outlet facilities, such as the utility trench containing the air vent and hydraulic lines for the main outlet of the dam.

2.0 BACKGROUND INFORMATION

During the September 25, 2008 site visit we observed geologic features that correlate with, and thus confirm, previous mapping of left abutment landslides by Jim Scott in 1977 and mapping of areas upslope of the boat ramp by Senior Engineering Geologist James Nelson on July 15, 2003.

Figure 1 is a compilation of mapping performed by James Nelson on July 15, 2003 and approximately 1 year later on July 19, 2004. The results of these field visits are discussed below. In addition, we superimposed the areal extent of the most recent manifestation of the landslide onto Figure 1.

The mapping on July 15, 2003 was in response to concerns expressed by FERC engineer Abbas Orumchian during an annual FERC inspection of Anderson Dam on July 8, 2003. During the July 8 annual FERC inspection, District and FERC personnel observed a relatively dense array of surface soil cracks on slopes where the Boat Ramp Landslide would eventually form that were thought to be related to new slope movements.

The findings from the July 15, 2003 mapping are summarized in an email dated July 16, 2003 from J. Nelson to R. Volpe. In the email, it was stated:

> *"There was concern during the FERC inspection that the cracking observed along the top of a prism of fill of the graded slope of location 1 was due to slope movement. However, detailed mapping indicates surface cracking at location 1 appears to be due to shrink-swell of expansive clay soils derived from Greenstone bedrock. Surface expression of the cracking was fairly randomly distributed, typical of expansive soils. The cracking was up to about 1 inch wide and ~3 inches deep. If cracking were due to slope movements one would expect*

> *to observe a linear series of cracking around the perimeter of the moving portion of slope. It would be prudent to make periodic inspections during the upcoming rainy season to evaluate the potential for slope instability."*

During the following annual FERC inspection District and FERC personnel observed the initial 2004 Boat Ramp Landslide. J. Nelson mapped the Boat Ramp Landslide on July 19, 2004 and summarized field findings in an email dated July 20, 2004 to R. Volpe. That email stated:

> *"The attached pdf file shows the earthflow landslide we observed yesterday (7/19/04) in the recently placed fill prism during our annual FERC dam safety inspection of Anderson Dam. The map is based on my original mapping of the fill on 7/15/03 after our 2003 FERC inspection on 7/8/03. In 2003, we observed a new prism of fill that was placed directly upslope of the new boat ramp during the recent improvements by the County Parks and Recreation. At that time we noticed cracking in the fill at upper elevations of the slope. With no knowledge of how the fill was constructed, or whether the fill had been properly keyed into the slope, we had concerns in 2003 with stability of the fill prism.*
>
> *Since our 2003 site visit a portion of the fill prism has failed producing an earthflow type landslide that we estimated to be about 30 feet wide, 40 feet long with a head scarp of about 4 feet deep. The map shows a photograph of the landslide viewed to the southeast taken from the dam crest showing the relationship of the fill and associated landslide to the boat ramp downslope and an access road/trail upslope".*

Figure 2 shows the aerial distribution of landslides mapped by Scott (1977) relative to the Boat Ramp Landslide. Scott mapped a landslide in the vicinity of the Boat Ramp Landslide, but he did not give it a specific designation. Thus, on Figure 2 we labeled it as "un-designated landslide". However, on Scott's original map he designated a large landslide complex to the east as Landslide "A" and two other landslides in the vicinity of the Boat Ramp Landslide as Landslide "B". In addition, Scott mapped a larger Landslide "C" that generally encompasses all mapped landslides. As discussed below, we interpret the "undesignated landslide" to be a precursor to the Boat Ramp Landslide. It appears likely this feature was a dormant landslide prior to widening of the boat ramp in 2003-2004.

The following are significant observations made during the July 15, 2003 mapping as shown on Figure 1.

1) Fairly extensive prisms of uncontrolled fill appeared to have been placed on the slope as a result of construction of the new boat ramp.
2) Widening of the new ramp resulted in removal of the native ground directly upslope of the ramp. The combined loading effect of adding fill to a slope underlain by the "undesignated landslide" and the unloading effect of cutting the toe of the slope appears to have contributed to reactivation of the "undesignated landslide" to produce the Boat Ramp Landslide.

For clarity, we relabeled the northernmost Landslide "B" as "B_1" and the southernmost Landslide "B" as "B_2". As shown on Figure 2, the Boat Ramp Landslide is situated at the right flank of the southernmost Landslide “B_2”. Also shown is the location of an inclinometer designated as SI-2 situated upslope of the head of the Boat Ramp Landslide. SI-2 is important because the keyway trench exposed inclinometer casing during our site visit on September 25, 2008. Also, the casing appeared to be significantly bent in a downslope direction indicating that active landslide movement had occurred in the vicinity of SI-2 since it was installed in 1972.

As discussed in more detail in section 3.1 Pertinent Observations of September 25, 2008, during the September 25th site visit we observed field evidence that substantiated the presence of uncontrolled fill likely placed on the Boat Ramp Landslide during construction of the new boat ramp.

3.0 CURRENT FINDINGS

This section summarizes pertinent geologic observations by Assistant Engineering Geologist Brett Baker and Senior Engineering Geologist James Nelson of additional landslide shear surfaces exposed during Boat Ramp Landslide Repair on September 25, 2008. Other personnel at the site included District Construction Inspector Dave Zozaya (Community Review Projects Unit), Dan Paluso (Geotechnical Engineer, Pacific Geotechnical Engineering), and Mohamed Assaf (Engineer, Santa Clara County).

During our site visit on September 25th, repair contactor Duran and Venables was placing compacted engineered fill in a keyway bench near the upslope end of the repair work area (see Figure 1). The bench consisted of a cut in the hillside that was approximately 10 feet high and ~20 feet long. By the time of our site visit, landslide repair work had involved removal and repair of most of the landslide mass of the Boat Ramp Landslide. Generally, repair consisted of cutting a keyway trench into relatively stable underlying soils and bedrock. As the keyway trench was excavated, removed soils were compacted as engineered fill back into the keyway trench. The contractor also constructed drains in the keyway trench based on landslide design parameters.

During previous site visits to observe landslide repair work on September 17, 18, and 23, 2008, we observed a likely main shear surface that marked the basal contact of the landslide mass that appeared to be the active Boat Ramp Landslide. Our observations indicated that the contractor was likely removing the active landslide mass including the shear surface down to relatively competent soil materials.

On September 17, 2008 the writer observed the probable Boat Ramp Landslide shear surface as a thin soft clay layer that marked the contact between upper red brown collluvium/ landslide mass and lower gray gravelly sandy clay derived from underlying Franciscan Complex mélange bedrock. Fairly competent weathered mélange bedrock was evident in the northeastern end of the keyway trench. However, the bedrock-residual soil contact quickly dropped down below the floor of the keyway trench to the southwest apparently due to deepening of an original swale and corresponding thickening of an old colluvial wedge in the vicinity of the landslide. Likewise, the basal landslide shear surface also dropped down below the keyway trench as the landslide mass became thicker to the southwest. It appears the Boat Ramp Landslide was confined to the thick colluvial wedge.

3.1 Pertinent Observations on September 25, 2008

Photo No. 1 and Photo No. 2 show pertinent features observed on September 25, 2008. Each of the photos has been annotated with pertinent geologic features further discussed below. During our site visit we observed at least two coalescing landslide masses marked by slightly polished striated (slickensided) landslide shear surfaces at the base of each landslide. According to the foreman of the project, the keyway trench floor elevation was located at approximately 648'. The approximate location of the keyway trench is shown on Figure 1. The writer measured the orientation of the trench wall to be S25^{O}W.

The trench also exposed a blue aluminum inclinometer casing, which we decided was probably the remnants of slope indicator SI-2 installed by the District in 1972 to monitor landslide movement in the left abutment area (Scott, 1977). Figure 2 shows the approximate location of SI-2 based on Scott's map. The casing was definitely for inclinometer surveys because it possessed four orthogonal grooves for an inclinometer probe. It is significant that the inclinometer casing was significantly bent at ~90 degrees from horizontal at a distinct polished landslide shear surface. This indicates that active landslide movement has significantly kinked the casing. The keyway trench excavation provided a unique opportunity to observe inclinometer casing kinked by active landslide movement.

Scott's 1977 report includes lateral movement plots of inclinometer SI-2 spanning approximately 4 years from an initial survey on 4-24-72 to a survey on 4-29-76 (Figure 8, Appendix 2). In his report Scott recommends that no further surveys be recorded for SI-2 after the 4-29-76 reading (1977). Active landslide movement is indicated by progressive lateral casing deflection of SI-2 between depths of 10 and 15 feet with an approximate maximum deflection of ~2 inches northward. During the 4 year period, monitoring data from SI-2 indicated an average landslide rate of ~0.5 in/year for Landslide "B_2". As mentioned above, Landslide "B_2" and inclinometer SI-2 are located in the immediate vicinity (upslope) of the Boat Ramp Landslide (see Figure 2).

Our review of Scott's 1977 mapping also suggests that the coalescing landslide shear surfaces observed in the trench headwall on September 25, 2008 are likely part of Landslide "B_2". Consequently, sloping ground in the vicinity of the Boat Ramp Landslide was actively moving during the early- to mid-1970s. We can assume that the precursor "undesignated landslide" to the Boat Ramp Landslide was also actively moving during this period, but may have been temporarily dormant sometime prior to reactivation in 2005 after the boat ramp was widened.

Photo No. 2 shows the general mapping of uncontrolled fill with a distinct contact marked by a dashed yellow line. The line denotes a contact between upper loose fill and lower relatively hard undisturbed sloping ground observed at two exposures provided by the contractor's excavator. The fill/ native ground contact consisted of a layer of buried grass, leaf litter, twigs and various organic debris that covered original ground surface before the uncontrolled fill was placed. This material is typical slope debris that was not stripped from ground surface prior to placement of the uncontrolled fill.

4.0 CONCLUSIONS

We made field observations to observe landslide repair work of the Boat Ramp Landslide under the direction of Santa Clara County Parks and Recreation on September 17, 18, 23 and 25,

2008. On September 25, 2008, we observed landslide shear surfaces in a keyway trench wall near the upslope head of the Boat Ramp Landslide that appeared to be basal shear surfaces of individual coalescing landslides, which appear to override the upper portion of the active Boat Ramp Landslide. It was decided to leave the upper landslides in-place because it was beyond the scope of the County's current effort to remove landslides other than the Boat Ramp Landslide.

A precursor to the Boat Ramp Landslide (labeled "undesignated landslide" on Figure 2) and Landslide "B_2" appear to have been active during the mid- to late-1970 as indicated by slope inclinometer data from SI-2 located immediately upslope of the Boat Ramp Landslide (Scott, 1977). The landslide may have been temporarily dormant until the re-activated Boat Ram Landslide was observed in July 2004 (Nelson, 2004). Also, it appears likely that the coalescing landslides observed in the headwall of the keyway trench on September 25, 2008 are part of Landslide "B_2".

Consequently, there is a remote possibility that future landsliding could occur in the vicinity of the Boat Ramp Landslide due to movement on the secondary coalescing landslides, which are likely a part of the much larger Landslide "B_2". They are considered coalescing landslides because the southwestern limb of one landslide and the northeastern limb of the other landslide appear to be draped over one another. It is significant that during our September 25 site visit we observed inclinometer casing SI-2 in the headwall of the keyway trench that appeared to have been bent due to active movement of Landslide "B_2". This substantiates previous landslide activity in the vicinity of the Boat Ramp Landslide; especially during the early 1970s (Scott, 1977). It appears likely that the repaired Boat Ramp Landslide may act as a buttress to the secondary coalescing landslides and thus minimize the possibility that new landsliding will occur in the vicinity of the repaired Boat Ramp Landslide.

Any future slope instability in the vicinity of the Boat Ramp Landslide will not likely affect the dam itself, but a reactivated landslide has the potential to adversely affect the District's outlet facilities, such as the utility trench containing the air vent and hydraulic lines for the outlet.

Our field observations on September 25, 2008, substantiated the presence of uncontrolled fill that was likely placed on the "undesignated landslide" (Figure 2) during construction of the new boat ramp. We observed and mapped the uncontrolled fill on July 15, 2003 in response to concerns by FERC that observed surface soil cracking on July 8, 2003 was indicative of new slope movements. During our Sept 25 site visit we observed the fill/ native ground contact as a layer of buried grass, leaf litter, twigs and various organic debris that covered original ground surface before the uncontrolled fill was placed. It appears likely that placement of the uncontrolled fill at the head of the likely dormant "undesignated landslide" combined with cuts made to the toe of the landslide during new boat ramp construction resulted in reactivation of the "undesignated landslide" to produce the Boat Ramp Landslide.

Original Signed By

James L. Nelson, C.E.G., C.H.G.
Senior Engineering Geologist
Dam Safety Program Unit

PROFESSIONAL GEOLOGIST
JAMES LEWIS NELSON
No. 1463
STATE OF CALIFORNIA

Attachments:

References Cited

Figure 1 – Map of Boat Ramp Landslide based on 7/15/03 and 7-19-04 mapping by J. Nelson
Figure 2 – Map of Left Abutment Landslides based on 1977 mapping by J. Scott
Photo No. 1 – View to southeast at Two Coalescing Landslides at Headwall of Boat Ramp Landslide Keyway Trench
Photo No. 2 – View to southeast of Uncontrolled Fill and Two Coalescing Landslides Upslope of Boat Ramp Landslide Keyway Trench

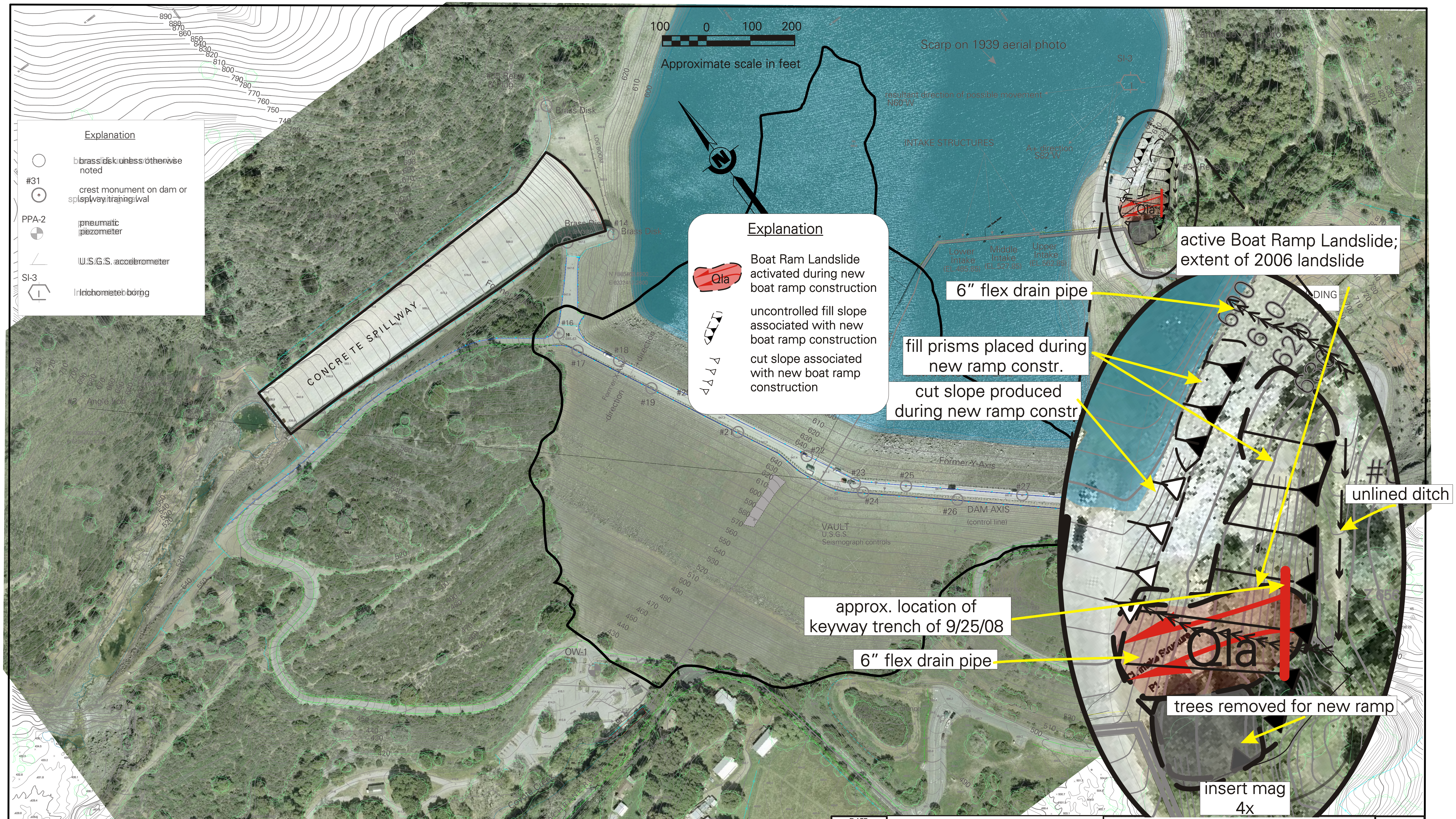
References Cited:

Nelson, J.L., email dated 6-16-03 to Richard Volpe, subject: Anderson Dam field mapping

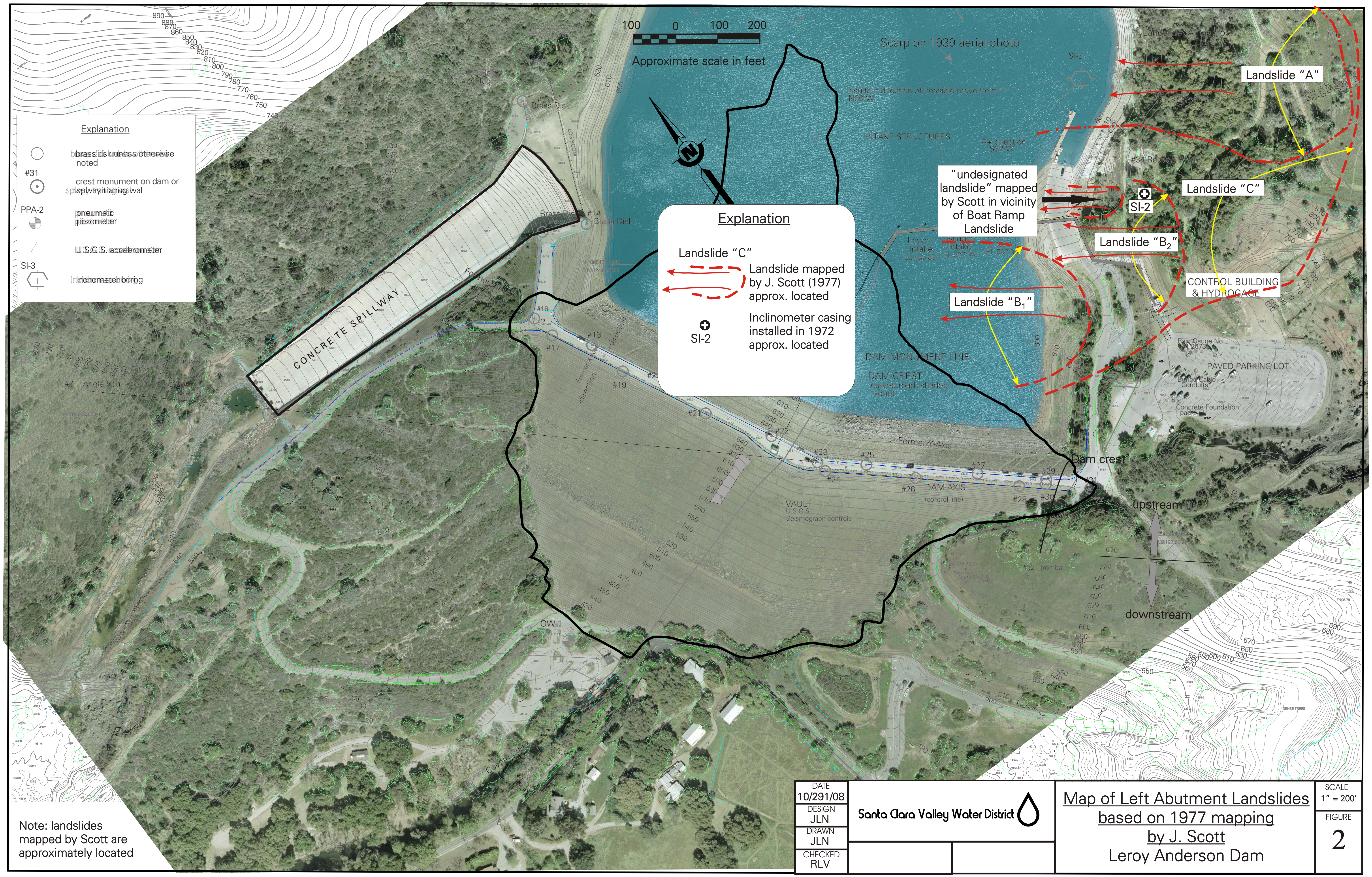
Nelson, J.L., email dated 6-20-04 to Richard Volpe, subject :pdf map of Anderson Dam fill prism landslide

Pacific Geotechnical Engineering, 2007, Draft Geotechnical Investigation Landslide Repair Above Boat Launch Ramp Anderson Reservoir County Park Santa Clara County, California: unpublished consultants report.

Scott, J.B., 1977, Left Abutment Landslides Anderson Dam: Office Report on file at the SCVWD


100 0 100 200
Approximate scale in feet
Scarp on 1939 aerial photo
resultant direction of possible movement N60 W
INTAKE STRUCTURES
Ax direction S82 W
Lower Intake
Middle Intake
Upper Intake
SI-3
Brass Disk
#14 Brass Disk
LOG BOOM
CONCRETE SPILLWAY
#16
#17
#18
#19
#20
#21
#22
#23
#24
#25
#26
#27
DAM AXIS (control line)
Former Y-Axis
VAULT U.S.G.S. Seismograph controls
OW-1
#2 Angle Iron
890
880
870
860
850
840
830
820
810
800
790
780
770
760
750
740
Explanation
brass disk unless otherwise noted
#31
crest monument on dam or spillway training wall
PPA-2
pneumatic piezometer
U.S.G.S. accelerometer
SI-3
Inclinometer boring
Explanation
Qla
Boat Ram Landslide activated during new boat ramp construction
uncontrolled fill slope associated with new boat ramp construction
cut slope associated with new boat ramp construction
Qla
active Boat Ramp Landslide; extent of 2006 landslide
6″ flex drain pipe
fill prisms placed during new ramp constr.
cut slope produced during new ramp constr.
unlined ditch
approx. location of keyway trench of 9/25/08
6″ flex drain pipe
Qla
trees removed for new ramp
insert mag 4x
600
610
620
630

DATE 10/291/08	Santa Clara Valley Water District	Map of Boat Ramp Landslide based on 7/15/03 and 7-19-04 mapping by J. Nelson Leroy Anderson Dam	SCALE 1″ = 200′
DESIGN JLN			FIGURE 1
DRAWN JLN			
CHECKED RLV			


100 0 100 200
Approximate scale in feet
Scarp on 1939 aerial photo
resultant direction of possible movement N60°W
INTAKE STRUCTURES
Landslide "A"
Landslide "C"
Landslide "B2"
Landslide "B1"
"undesignated landslide" mapped by Scott in vicinity of Boat Ramp Landslide
SI-2
SI-3
CONTROL BUILDING & HYDROGAGE
Rain Gauge No.
PAVED PARKING LOT
Concrete Foundation pad
Explanation
Landslide "C"
Landslide mapped by J. Scott (1977) approx. located
Inclinometer casing installed in 1972 approx. located
SI-2
DAM MONUMENT LINE
DAM CREST (paved road, shaded zone)
Former Y-Axis
Dam crest
upstream
downstream
DAM AXIS (control line)
VAULT U.S.G.S. Seismograph controls
CONCRETE SPILLWAY
Brass Disk
#14 Brass Disk
#16
#17
#18
#19
#21
#22
#23
#24
#25
#26
#27
#28
#29
#30
#31
OW-1
#2 Angle Iron
LOG BOOM
Explanation
brass disk unless otherwise noted
#31
crest monument on dam or spillway training wal
PPA-2
pneumatic piezometer
U.S.G.S. accelerometer
SI-3
Inclinometer boring

Note: landslides mapped by Scott are approximately located

DATE 10/291/08	Santa Clara Valley Water District	Map of Left Abutment Landslides based on 1977 mapping by J. Scott Leroy Anderson Dam	SCALE 1" = 200'
DESIGN JLN			FIGURE 2
DRAWN JLN			
CHECKED RLV			

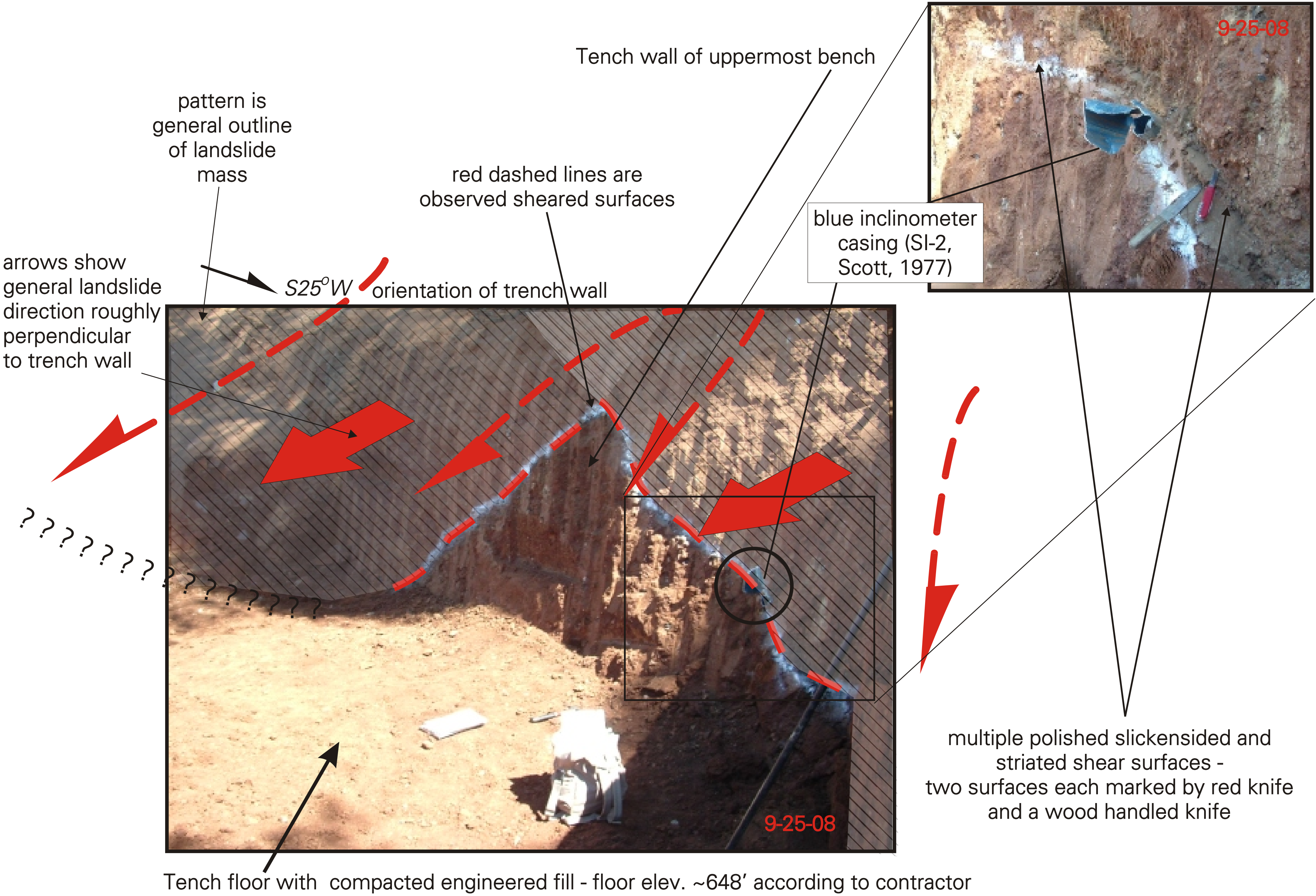
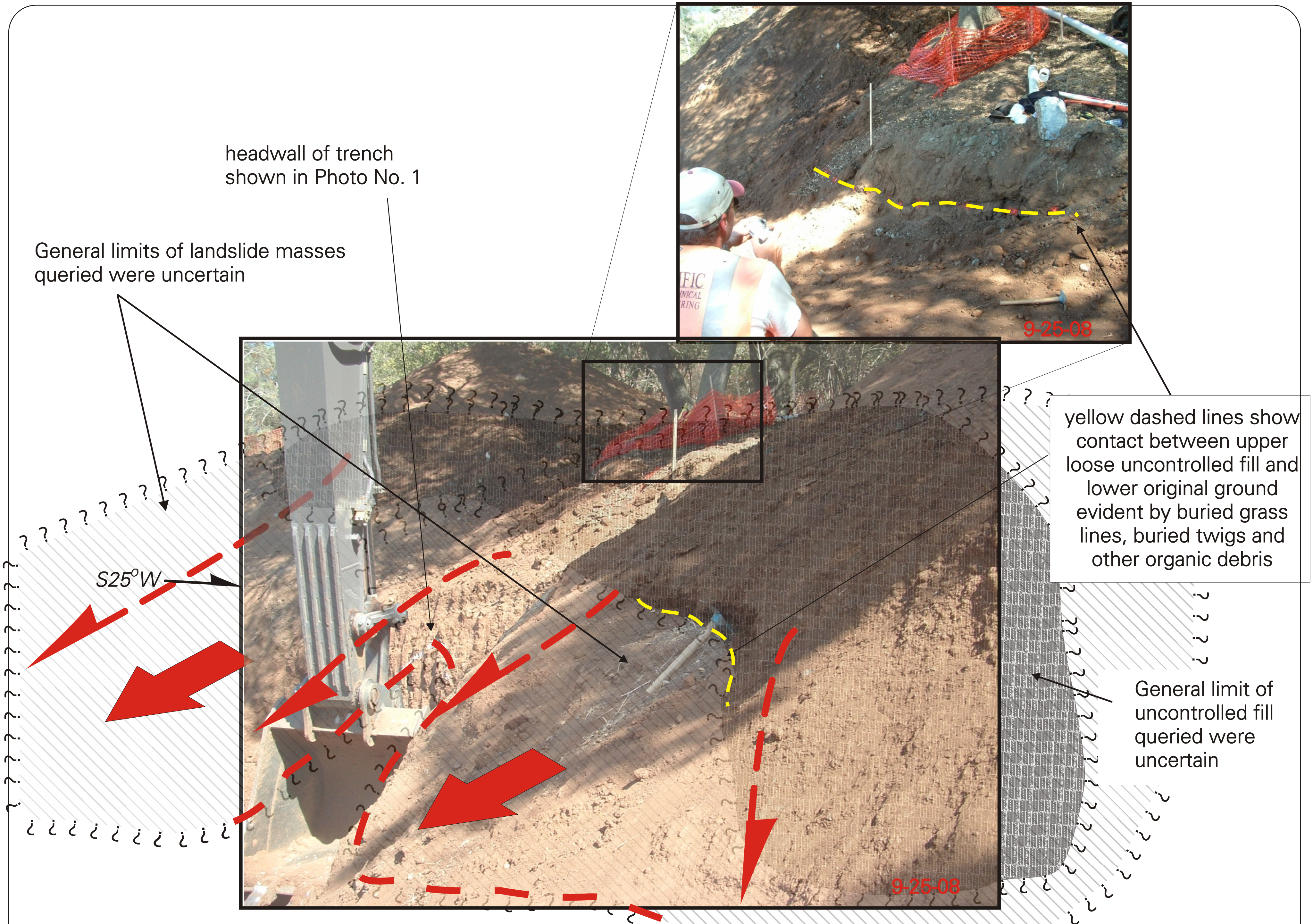

Tench wall of uppermost bench
pattern is general outline of landslide mass
red dashed lines are observed sheared surfaces
blue inclinometer casing (SI-2, Scott, 1977)
arrows show general landslide direction roughly perpendicular to trench wall
S25°W orientation of trench wall
? ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? ?
9-25-08
9-25-08
multiple polished slickensided and striated shear surfaces - two surfaces each marked by red knife and a wood handled knife
Tench floor with compacted engineered fill - floor elev. ~648′ according to contractor

Photo No. 1 - View to southeast at Two Coalescing Landslides at Headwall of Boat Ramp Landslide Keyway Trench



headwall of trench
shown in Photo No. 1

General limits of landslide masses
queried were uncertain

yellow dashed lines show
contact between upper
loose uncontrolled fill and
lower original ground
evident by buried grass
lines, buried twigs and
other organic debris

General limit of
uncontrolled fill
queried were
uncertain

Photo No. 2 - View to southeast of Uncontrolled Fill and Two Coalescing Landslides Upslope of Boat Ramp Landslide Keyway Trench